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ELEMENTS

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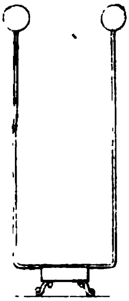
PLATE III.

Fig 17.



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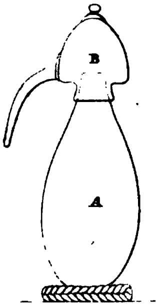

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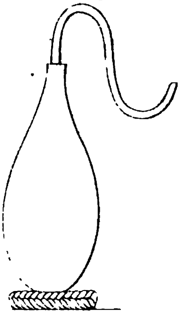

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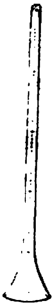

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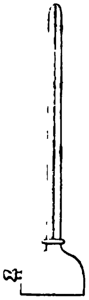

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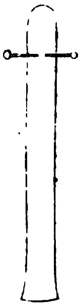

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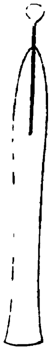

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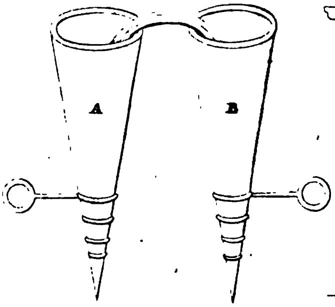

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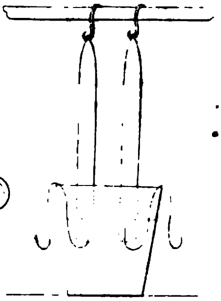

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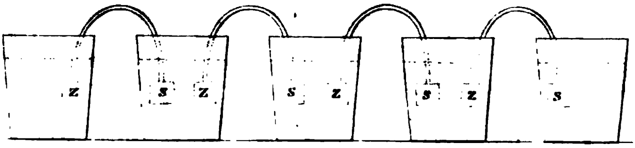

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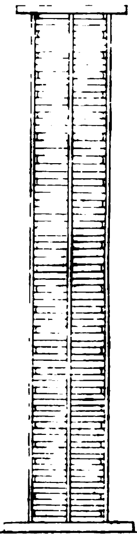

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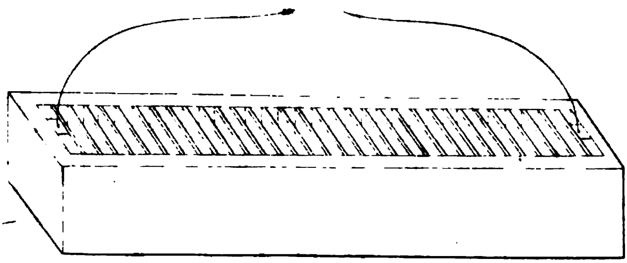

J. Grant Sculpt

ELEMENTS

OF

CHEMISTRY.

BY

J. MURRAY,

LECTURER ON CHEMISTRY, AND ON MATERIA MEDICA
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BOOK VI.

OF METALS, AND THEIR COMBINATIONS.

OF all the classes of inanimate natural productions, that of Metals appears to be best defined, the substances united under it having qualities extremely appropriate. Their peculiar lustre, perfect opacity, great density, and tenacity, are properties which, to the same extent, belong to none of the other varieties of matter, and which possessed by each metal, serve to distinguish it without ambiguity.

The progress of science has, however, in this as in many other examples, modified or subverted our artificial distinctions. Of these characteristic qualities, that of tenacity, under the forms of ductility and malleability, has been found not to belong to all the substances referred to the class; and still more recently, the discovery of the bases of the alkalis and earths has demonstrated, that a high degree of density is not possessed by substances which have all the other metallic properties. The ideas connected with an established system of classification, in some measure oppose the changes to which such discoveries lead. The metals destitute of ductility and malleability were for a time placed as a subordinate order, under the appellation of Semi-metals; and chemists at present hesitate whether the alkaline and earthy bases are metallic. We can scarcely, however, on any principles of sound arrangement, refuse them this rank; and it is only because the established system of chemical knowledge is still so much connected with the former distinctions, and that time is required to mature such innovations, that I have already considered the alkalis and earths as distinct orders, and have given under their history that of the metallic bases of which they are formed.

Excluding these substances, the number of substances admitted as metals amounts to twenty-seven. Seven of these only were known to the ancients, and of the others the greater number is of very recent discovery, and some of them have only doubtful claims.

Of the physical properties characteristic of the metals, that of *density* used to be regarded as one of the most distinctive. The specific gravity of fossil substances not metallic seldom exceeds 2 or 3, water being 1, and the heaviest of them is not more than 4.5, while the lightest of the metals exceeds 6, and many of them are more than ten times heavier than water. The metalloids, as the substances obtained from the alkalis and earths have been named, are, however, lighter than water.

Opacity so far belongs to the metals, that when in the thinnest plates into which they can be reduced without the continuity being broken, they transmit no light, while the most opaque substance of any other class becomes translucent under a similar mechanical division. The only exception with regard to the metals, is afforded by gold, which, in very thin leaves, transmits a green light, a proof that the property is merely relative, and that transparency would be acquired under a sufficient extension. Still opacity peculiarly belongs to the metals, and in conjunction with the peculiar lustre to which it gives rise, is the only property strictly characteristic; for now that the properties of density, of ductility, and malleability, cannot be regarded as essential, there is nothing in the diamond, and perhaps even in sulphur, but their transparency, that can prevent them from being ranked as metallic. And as the assigning the property of opacity alone, as distinctive of metals, would be imposing a mere arbitrary distinction, all these substances strictly belong perhaps to one class.

The opacity of the metals, and the closeness of their texture, causing the entire reflection of light from their surface, they hence possess a high degree of *lustre* or brilliancy. Many of them lose this from the tarnish they suffer from exposure to the air; but in their fresh fracture they all exhibit it. It is increased also by the high polish of which they are in general susceptible.

The property of tenacity, or strong cohesion of parts, appears in the metals under two forms, *ductility* and *malleability*. By the former is understood that modification of tenacity whence a body can be drawn into fine wire; by the latter, that in consequence of which it can be beat or extended into thin leaves. Though both properties are connected, they are still distinct, and are possessed in very different degrees by different metals. Where hardness accompanies tenacity, the extension into leaves is difficult, while that into wire is easily executed; hence iron can be drawn into finer wire than any other metal, or possesses the greatest ductility, while it has little malleability. Platina has nearly the same character. In the soft metals, on the contrary, tenacity appears usually under the form of malleability; thus gold, tin, and lead, can be extended in thin plates, without being capable of being drawn into very fine wire. Silver and copper, being metals of medium hardness, have both properties, nearly perhaps in equal proportions. In a number of the metals, the brittleness is such as to prevent their extension to any great degree of fineness under either form. The extension of the metals is facilitated by a certain degree of temperature, this favouring their expansion, increasing the distances between their particles, and probably lessening their hardness or rigidity; but if heated beyond a certain temperature, brittleness is communicated probably from the attraction of cohesion being weakened. Hence the metals are in general brittle when heated near to their melting-point.

The quality of *hardness* belongs to the metals, but is possessed by the different metals in very different degrees, so as to serve as one of those properties by which the individuals of the class may be distinguished from each other. In all of them it can be increased by different artificial methods, principally by cooling them suddenly when they have been highly heated. This hardness, acquired from the hasty approximation of the particles, is accompanied with a corresponding degree of brittleness. The softness and tenacity can be restored by again heating them, and allowing them to cool slowly.

In their relations to caloric, metals observe the same general laws as other bodies. They are superior to all others in conducting power. Their *fusibility* is very various. Quicksilver is so fusible as to require a reduction of temperature equal to —40° to congeal it; while other metals, as molybdena, or manganese, can with the utmost difficulty be fused. In congealing, they so far assume a crystalline arrangement as to exhibit an internal structure peculiar to each; and by slow cooling, several of them can be made to assume regular crystalline forms, generally those of the cube and octaedron. In volatility they are likewise extremely various. Quicksilver passes into vapour *in vacuo* at natural temperatures; it boils under a medium atmospheric pressure at a temperature a little below 700. Arsenic is even more volatile, while the greater number require very intense heats to convert them into vapour.

Metals, in relation to electricity, conduct it better than any other bodies. They evolve it by mutual contact, whence their power of generating galvanism.

Metals exert affinities to other substances, so as to be susceptible of numerous combinations. They unite with oxygen, with sulphur, phosphorus, and carbon, and with each other; and when combined with oxygen, they farther combine with acids, and in general with alkalis and earths. Of these combinations, that with oxygen is the most important, and a number of general facts have been established with regard to it.

The combination of a metal with oxygen in general takes place, when it is favoured by a sufficient elevation of temperature; and it is this which constitutes the striking and important change which many metals suffer when heated under exposure to the air. The metal loses its lustre, scales form upon its surface, and as this proceeds, it loses altogether its tenacity, density, and other characteristic properties; and is converted into a powder, dull, and in general earthy in its appearance. This process was formerly named Calcination, and the product was denominated a Metallic Calx. According to the theory of Stahl, it arose from the dissipation of the phlogistic or inflammable principle, which he supposed to exist in metals in common with inflammable substances; and the product of the process, according to this view, is the substance or base of the metal, with which the phlogiston had been combined. The important fact, however, had been established, with regard to several metals, that the metal, in suffering this change, increases in weight—a fact altogether at variance with the hypothesis: it had been farther discovered, that the admission of the air is necessary to the process. Bayen, about the period of the commencement of the researches of pneumatic chemistry, discovered the very important fact, that from certain metallic calces, particularly those of quicksilver, a large quantity of aerial fluid might be expelled by the application of heat in close vessels, the calx at the same time returning to the metallic form. The weight the metal gains in calcination he ascribed to the absorption of this aerial fluid, and his experiments he regarded therefore as so far subversive of the theory of Stahl. It was afterwards discovered, that the air thus expelled is oxygen gas; it was shewn by more ample and decisive evidence, that the presence of atmospheric air is indispensible to metallic calcination; it was proved, that the air suffers during the process a diminution of volume and weight; that this is owing to the abstraction of part of its oxygen; and that the increase of weight which the metal suffers, is equivalent to the weight of the quantity of oxygen which disappears. Lavoisier, by whom some of these facts were established, concluded from them, that the calcination of a metal is merely its combination with oxygen, and that the general process is therefore so far analogous to the process of combustion.

The oxidation of a metal, by the agency of atmospheric air, takes place in different metals with different degrees of facility. In general, it is necessary to raise the temperature considerably higher than a natural temperature, and to many of them it is necessary to apply very intense heats. Some are oxidated at the temperature at which they melt; others, even when in perfect fusion, undergo no change; some are oxidated when the heat is raised sufficiently high to convert them into vapour; and others, as gold or platina, resist oxidation at either temperature, and can scarcely be made to undergo it from the action of oxygen in its elastic form. The application of heat, in promoting metallic oxidation, is to be explained on the same principles as its agency, in favouring in general chemical combination. It acts by lessening the cohesion of the metal, which is an obstacle to the combination; this is concentrated, however, to a certain extent, by its necessarily augmenting the elasticity of the oxygen gas;

and hence, where the mutual affinity between the metal and the oxygen is weak, the combination is not effected.

The phenomena which accompany the combination of a metal with oxygen, are various. In general, it takes place slowly, and hence there is scarcely any sensible evolution of light, and no such extrication of caloric, as to enable the combination to proceed independent of the continued application of heat. In some, however, the oxidation is so rapid as to give rise to the phenomena of combustion: thus zinc and iron burn vividly at a temperature a little higher than that of ignition; tin and arsenic burn at the same temperature, with a more feeble flame; and at more intense heats, nearly all the metals suffer combustion.

The substances formed by the combination of oxygen with metals, are in general oxides. With regard to several of them, however, the oxidation can also be carried so far as to produce compounds with distinct acid powers.

Metallic oxides have few common characteristic properties. They are usually of an earthy appearance, without the lustre, tenacity, or density of the metals. Several of them may be vitrified, when they form glasses more or less transparent, of dark colours. Their chemical relations are entirely different from those of the metals; they exert affinities to the acids, alkalis, and earths, and in their combinations with acids, neutralize the acid properties. In these properties they are analogous to the alkalis and earths; and in strictness of chemical arrangement, they probably form with these substances only one class. The common metallic oxides differ from the alkalis, and several of the earths, in being less soluble in water, whence they display less energy in chemical action.

In combining with oxygen, the metals unite with different proportions of it; the proportion for example, in oxide of gold or silver, does not exceed 7 parts in 100, while in that of iron or manganese, it equals or exceeds 40. If the quantity condensed can be regarded as a measure of the force of affinity which the metal exerts, as Berthollet's views of chemical attraction suggest, we should have a correspondence apparently strict between this criterion and that which is afforded by the comparative facility and difficulty of decomposition; for of the above oxides, those of gold and silver are decomposed with great facility, while the entire decomposition of those of iron and manganese is extremely difficult.

Each metal, in combining with oxygen, combines too with different proportions of it, and these combinations, in conformity to the usual law of chemical attraction, give origin to compounds having very different properties. Quicksilver, with a small proportion of oxygen, forms an oxide of a grey colour; with a large proportion of oxygen, it forms one which is red; manganese forms a white and a black oxide, iron a black and a red; and there are others in which the degrees of oxidation are more numerous, marked by differences of properties sufficiently distinctive. The force with which the oxygen is retained in these combinations is different, being less strong as the proportion of oxygen is greater, from the influence of quantity on chemical affinity. Hence the partial decomposition of an oxide can often be easily effected, while the entire deis not variable, the oxide will always be uniform, or one determinate proportion will be observed in the combination. The oxide formed at the point of the volatilization will, from a similar cause, be always the same. And the affinities of acids, and the cohesion of crystallized metallic salts, are often sufficiently powerful to determine the combination, or place limits to the proportions in which it takes place.

It follows, from these observations, that no precise nomenclature can be applied to the denomination of the metallic oxides. To attempt to establish distinctive appellations of the different oxides of the same metal, on supposed determinate and constant degrees of oxidation, would be only to introduce a source of error, which in the progress of the science would be productive of much confusion. The distinctions of the oxides are generally, and perhaps most conveniently, drawn from qualities in which they differ. Colour, as it is the most obvious, is the most usual. But where this is not sufficiently distinctive, the distinction may be drawn from other properties.

Metallic oxides may be decomposed, the oxygen being abstracted, and the metal obtained again in its metallic state. This constitutes the process named Reduction, and it is effected in various modes.

The oxides of some metals are reduced by the operation of caloric alone; those of gold, silver, and quicksilver, are thus reduced by a heat not much superior to that of ignition; and others, by elevation of temperature, suffer at least a partial reduction.

In general, however, it is necessary to introduce the more powerful agency of other substances exerting an affinity to oxygen. Charcoal is the one most powerful and most convenient in its operation; and hence, the oxides of all the metals, when exposed to a heat sufficiently intense, in mixture with charcoal powder, or with matter capable of being converted into charcoal, as any vegetable substance, are reduced, the carbonaceous matter combining with the oxygen of the oxide, and forming carbonic acid, carbonic oxide, or portions of both, according to the proportions employed, or the force of affinity with which the oxygen is retained. The metal, thus deprived of oxygen, is at the same time fused. The addition of some substances favour the operation by melting, and thus communicating that state of fluidity favourable to chemical action, or by a resulting affinity aiding the formation of carbonic acid by the union of the carbon and oxygen. Carbonate of potash mixed with charcoal, under the form of what is named the *black flux*, prepared by calcining a mixture of one part of nitre with two of tartar, is generally used for this purpose, in experiments on a small scale. In reduction performed on a large scale, lime is useful, partly by the same operation, and partly by contributing to the vitrification and removal of any earthy matter.

Metallic oxides may be reduced by the action of other substances, exerting a strong attraction to oxygen, as, for example, by hydrogen; and even one metal, under certain circumstances, reduces the oxide of another. Light reduces them partially or entirely, as has been already stated; and they are decomposed when placed in the galvanic circuit, from the different relations of oxygen, and of metallic matter, to the different galvanic poles.

Besides the direct action of oxygen in its elastic form on metals, there are other cases in which the same ultimate result is produced by the transfer of oxygen from compounds in which it exists. Thus metals are oxidated by deflagration with nitre, and by the action of acids, and of water; and these, being more complicated, present some peculiar phenomena.

If a metal be exposed to a high temperature in mixture with nitre, the oxygen disengaged from the decomposition of the acid, combines with the metal, and usually with such rapidity as to produce the phenomena of combustion or deflagration. With regard to several of them, however, a very high temperature is necessary for this; and those which have a weak attraction to oxygen, particularly gold, silver, and platina, suffer the change imperfectly. Those which are more susceptible of oxidation, are in general by this process oxidated to the *maximum*, and frequently the oxide exerts an affinity to the potash, and combines with it. A similar oxidation of metals may be effected by the agency of the hyper-oxymuriate of potash; and mixtures of this salt with a number of the metals detonate from percussion, as has been already stated.

These metals which have a strong attraction to oxygen, receive it from water. Some of them, as iron, do so at a low temperature. At a high temperature, it takes place more rapidly, as it does also at a low temperature, when promoted by the disposing affinity of an acid.

Acids are, of all the classes of chemical agents, those which act with greatest force in oxidating metals; the acid either directly imparting oxygen to the metal, enabling the metal to acquire it from the decomposition of water, or sometimes by absorption from the atmospheric air. According as one or other of these effects is produced, the action of an acid on a metal is attended with peculiar phenomena. If the acid act by directly affording oxygen, the action is attended with the evolution of the other constituent principle of the acid, either pure or partially oxidated: if it operate by enabling the metal to attract oxygen from the water which is present, then it is accompanied with the disengagement of hydrogen gas. Nitric acid always directly imparts oxygen to metals; and in consequence of this decomposition, nitric oxide, nitrous oxide, or nitrogen gas, is disengaged. Sulphuric acid scarcely suffers decomposition, unless the affinity of the metal to oxygen be aided by a high temperature; and hence, in its concentrated state, it does not act forcibly on metals in the cold; but when diluted, its action is powerful in oxidating the metal by the decomposition of the water. The action of muriatic acid is similar; and hence, those metals only are oxidated by it, as well as by diluted sulphuric acid, which are capable, when aided by the resulting affinity of the acid, of decomposing water. The principles of nitric acid being united by a weaker affinity, it is more susceptible of decomposition; and hence it acts on all the metals, gold and platina excepted, the affinity of these to oxygen being not sufficiently powerful to decompose it.

The effect of an acid, in those cases in which it promotes the oxidation of a metal by the decomposition of water, is an example of what is named Disposing or Resulting Affinity, or it depends on the united force of attractions, which, but by their co-operation, would not be apparent,—the attraction of the metal to oxygen, of the acid to oxygen, and of the acid to the metal. These co-operating overcome the single affinity of the oxygen to hydrogen; hence the water is decomposed, and the metal, the oxygen of the water, and the acid, enter into one combination.

In a few cases, an acid promotes the oxidation of a metal, by enabling it to attract oxygen from the air. This kind of action is generally exerted by acids of weak power. It is well exemplified in the action of diluted acetic acid on copper or lead.

The action of an acid on a metal, is not limited merely to its causing its oxidation: as the oxidation is effected, the acid uniformly combines with the oxide, and it is this which constitutes the solution of metals in acids. No acid directly combines with a metal, the metal must always be oxidated; hence, if an acid act on a metal, it does so always by first communicating to it oxygen directly or indirectly in the modes above explained, and at the same time it combines with the oxide as it is formed. And hence, the compounds thus formed are the same with those which would be produced, if the acid more directly combined with the metal previously brought to the same state of oxidation by any other mode. If the compound of the oxide and acid is insoluble, or of sparing solubility, it is precipitated as the mutual action proceeds; but if it is sufficiently soluble, it remains in solution in the water of the acid, generally retaining an excess of acid in the combination.

The base, therefore, in immediate union with the acid in all these combinations, is not the metal, but the metallic oxide. It produces perfect neutralization of the acid when the combination is established in the due proportions. These compounds are strictly analogous to those formed by the combination of the alkalis and earths with the acids; they are many of them soluble in water and crystallizable. Being thus of a saline nature, they have been denominated metallic salts; and the same nomenclature is applied to them as to the other orders of compound salts; those which contain sulphuric acid being named sulphates, those containing nitric acid, nitrates, and the same mode being followed with regard to the others. The species is named from the metal which is the ultimate base, as sulphate of iron, nitrate of copper, &c. In the strictness of system, the name ought to be derived not from the metal, but the metallic oxide, as it is this which is the primary base, or is in immediate combination with the acid; but the other nomenclature has from its conciseness been preferred.

Every metal being susceptible of different degrees of oxidation, it is obvious that the same metal may with the same acid form different compounds, according as it is more or less highly oxidated. This accordingly gives rise to striking differences in these combinations, and to a number of important facts with regard to them.

The difference in the nature and properties of these compounds from the different states of oxidation in which the metal exists combined with the acid, is apparent in many examples. Thus there is one muriate of mercury insipid, insoluble, and extremely mild; but there is also another in which the metal is more highly oxidated, soluble, and in the highest degree acrid and corrosive.

The facts with regard to the production of these compounds, and the state of oxidation in which they exist, admit of a certain degree of generalization, under which they may be best enumerated. The following are the most important. 1*st*, When a metal is acted on by a diluted acid, or by one having not much energy of action, it is usually less highly oxidated than when acted on by one more powerful, or which, from facility of decomposition, affords oxygen more readily. 2*d*, When the solution takes place in the cold, the degree of oxidation is less considerable than when the mutual action is favoured by heat. 3*d*, The oxidation of the metal may at first be at the *minimum*, but it may pass to a higher degree, from exposure to the air, a quantity of oxygen being absorbed; or a similar change may be produced from a farther decomposition of the acid in the combination, this happening more particularly when heat is applied. 4*th*, The affinity of the metallic oxide to the acids changes as the oxidation varies, becoming in general less powerful, as the degree of oxidation is greater: hence a metal highly oxidated may be insoluble in an acid in which it may be dissolved at a lower degree of oxidation; hence too the cause of a common occurrence displayed by metallic solutions, that from exposure to the air, and sometimes from exposure to heat, they suffer a partial decomposition, a portion of precipitate being thrown down. The change in this case is owing to the metal passing gradually to a higher state of oxidation, and to the affinity of the acid to it, as this takes place, becoming less powerful; whence the whole of the oxide cannot be retained in solution, but a portion of it is precipitated, retaining a little of the acid combined with it. To this also is to be ascribed the fact, that some metallic oxides in a high state of oxidation are insoluble in sulphuric or nitrous acid, but are dissolved by sulphurous, nitrous, or muriatic acid; the latter acids abstracting a portion of the oxygen of the oxide, and, in conformity to this law, allowing the more powerful affinity to be exerted. *Lastly*, from the same cause, one metallic oxide may precipitate another, from its combination with an acid, the action of the one, at a low state of oxidation, being more powerful than that of the other in a higher state of obidation.

When a metal combines at different degrees of oxidation with an acid, are these degrees always determinate; or may it enter into these combinations in degrees of oxidation indeterminate, or at all stages intermediate between the *minimum* and *maximum?* This is an important, and at the same time a difficult question, in relation to the subject of metallic solution. In general, perhaps, it may be affirmed, that in these combinations determinate degrees of oxidation are established, this being done by the powerful affinity of the acid to the metal in a certain state of oxidation. But frequently it appears also, that the degrees of oxidation are indeterminate, or at least are numerous, and not easily obtained uniform.

The different states of oxidation in which a metal can exist in combination with an acid, give rise to a difficulty with regard to the nomenclature of these compounds; the name of the genus of each series being derived from the name of the acid, that of the species from the name of the metal, it is difficult to convey by the designation, in what state of oxidation the metal exists. Yet nothing frequently is more important than to do this, the different salts formed from the acid and the same metal differing widely in their properties in different states of oxidation, and requiring therefore to be carefully distinguished. The method which appears to be most practicable, and least likely to lead into error, is to derive distinctive epithets, attached to the usual names, from differences in the properties of such salts: we thus speak of the green and the brown sulphate of iron, the mild and the corrosive muriate of mercury. Any method founded on the supposition of determinate degrees of oxidation being established in these compounds, can only lead into error; for were even the supposition just, which it probably is not, all the possible degrees of oxidation cannot be presumed to be exactly known, and the discovery of a new degree of oxidation in the series of the compounds of one genus would require a change of nomenclature through the whole, or at least with regard to all those at a higher degree of oxidation; and what is worse, the names which had been appropriated to some would, in this change, require to be applied to others. The method which some have employed, of prefixing the epithet *oxy* to the usual generic name, to distinguish the compound of the metal at the higher state of oxidation, can serve to distinguish only two compounds of each metal with one acid, while the number may be greater; and is besides incorrect, the syllable *oxy* being, in the system of modern nomenclature, appropriated to distinguish the compounds of oxygenated acids.

The metallic salts, like the other orders of compound salts, may exist with various proportions of their constituent principles. When these are united in one proportion, the state of neutralization is established; but besides this, combinations may be formed in which there is an excess of acid, or an excess of oxide. When the base predominates, the compound is usually insoluble, and many such combinations have been even regarded as pure oxides; when there is an excess of acid, solubility is communicated; and it is difficult to cause the compound to crystallize. These combinations appear to be unlimited with regard to proportions, or, in all cases, the oxide and the acid may be united in any relative quantity with regard to each other; and in these, as in other cases of chemical union, determinate proportions are established only by the operation of cohesion, or other external forces.

Metallic salts are in general more susceptible of decomposition than the other orders of compound salts. Many of them are decomposed by the action even of water, which exerting a stronger attraction to the acid than to the oxide, combines with the greater portion of it, and hence subverts the combination, instead of merely dissolving it. In this case the usual participation of substances acting on each other takes place; the acid dissolved by the water retains a little of the oxide combined with it; the oxide which is precipitated, retains a small portion of the acid in combination with it; and the neutral metallic salt is thus resolved into two compounds, one with an excess, the other with a deficiency of acid.

The action of an alkali, and likewise of any of the soluble earths, on these metallic combinations is similar, only more energetic. The alkali exerting a stronger attraction to the acid, abstracts a larger portion of it, but the oxide in its separation still retains a little of the acid in combination with it, and frequently the acid, in entering into union with the alkali, carries a small proportion of the oxide along with it. The oxide which is precipitated generally retains less acid combined with it, than when the decomposition is effected by water, and chemists were even accustomed to regard these precipitates as pure oxides; but, however powerful the action of the alkali may be, or however large the quantity in which it is used, its action is opposed more powerfully, in proportion as the decomposition proceeds, by the increasing relative quantity of oxide to the remaining acid: hence the abstraction of the acid is seldom complete.

The alkali sometimes, in decomposing those salts, reacts on the oxide, and dissolves a portion of it, or when added in excess, forms with it and the acid a ternary combination. Ammonia has in particular this tendency, and sometimes too it has been supposed to decompose the oxide partially, its hydrogen attracting a portion of the oxygen, and thus reducing it more nearly to the metallic state.

The metallic salts, like the other compound salts, are liable to decomposition, from the different relations of the different acids to their bases. Thus many of the metallic nitrates are decomposed in the humid way, by the addition of sulphuric, muriatic, or phosphoric acid; and by the application of heat, other similar decompositions are produced, the acid combined with the oxide being disengaged by another acid which takes its place. Similar decompositions may be produced by double affinity. All of these used to be ascribed to the relative forces of affinity exerted by the different acids to the oxides; but, like all similar decompositions, they arise as much from the exertion of cohesion, elasticity, and other external forces, by which chemical attraction is modified.

There is one kind of decomposition peculiar to the metallic salts, that in which the oxygen is abstracted from the oxide, so that it is reduced to the metallic state. This kind of decomposition is generally produced by one metal acting on the solutions of another; thus iron precipitates copper from its saline combinations, and copper precipitates silver or quicksilver.

It was conceived, that in these cases the decompositions arise merely from the relative forces of affinity of the metals to oxygen; the metal which is precipitated from any of its saline solutions, being supposed to have a weaker affinity to oxygen than the metal which precipitates it; the latter therefore attracting the oxygen from the former, the one becomes insoluble, and is separated in its metallic form, while the other, by its combination with oxygen, becomes capable of combining with the acid with which the oxide of the other had been united, and is dissolved in its place. The acid is thus regarded merely as the medium which, by communicating fluidity, allows these affinities to be exerted. This view is probably partly just, yet there can be no doubt, that the actions exerted are more complicated, and that both the acid, by its affinities to the oxides of the respective metals, modifies the results, and that a similar modification is produced by the affinity of the precipitating to the precipitated metal. A proof of the influence of the latter circumstance is derived from the fact, that the metal precipitated has generally a small portion of the other metal combined with it.

If the precipitation in these decompositions takes place slowly, the metal assumes somewhat of a crystalline arrangement, and the accretion of new matter has been observed to take place from the extremities of the filaments already formed, a phenomenon which has been considered as galvanic. Sometimes the abstraction of oxygen is only partial, the one metal attracting part of the oxygen from the other, and both oxides being precipitated.

Similar decompositions are produced by some inflammable substances, as by hydrogen, charcoal, and phosphorus, especially when their action is favoured by the chemical agency of light.

The alkalis exert scarcely any sensible action on the metals in their metallic state; they combine, however, with a number of the metallic oxides, dissolving them in the humid way, and by the application of heat, forming compounds which are sometimes capable of being vitrified. In these combinations the opposite law appears to be observed, from that which regulates the combination of the acids with the metallic oxides,—the affinity exerted by the alkali being more powerful to the oxide in a high than in a low state of oxidation, and these combinations being hence usually established in the former state. The solutions of certain metallic oxides in alkaline liquors may be decomposed, according to Klaproth, by the action of another metal attracting oxygen from the one which had been dissolved, and precipitating it in its metallic form.

The metals form no combination with nitrogen. Hydrogen, even in its elastic form, is capable of retaining a small quantity of some of them dissolved.

Carbon unites with some of the metals, particularly with iron. Plumbago is a natural, and steel an artificial compound of this kind. Carbon unites too with zinc, but not in any appreciable quantity, so far as has been ascertained, with any of the others.

Sulphur combines with all the metals by fusion, gold and zinc excepted; its combination with some of the metals being attended, as has already been remarked, with the evolution of heat and light, or the sensible phenomenon of combustion, no doubt from a similar cause as that which gives rise to the same phenomena in the combinations of oxygen with combustible bodies,—a diminution in the capacity for caloric, and a change in the chemical relation of the compound to the light existing as a constituent principle in one or both of the bodies combined. The effect has no connection with oxygenation, for it takes place when the metal and sulphur are heated *in vacuo*; the compound is found to be a pure sulphuret, and it is not promoted by the presence of a portion of oxygen, neither heat nor light being evolved, when the metal is employed in the experiment in the state of an oxide.

The compounds of the metals with sulphur have a lustre approaching to metallic; they are opaque, hard, and brittle, and generally more fusible than the metal of which they are composed. The proportions of their constituent principles have been supposed to be uniform and determinate; but there is more reason to conclude, that they are variable and indeterminate. The attraction by which they are combined, is in general sufficiently strong to prevent the expulsion of the sulphur by heat, or at least to render it only partial; and the decomposition is obtained more completely, only by admitting at the same time the operation of the atmospheric air, the oxygen of which, combining with the sulphur, converts it into sulphurous acid, which the heat expels. By the mutual action of the metal and sulphur, their affinity to oxygen appears to be promoted; and these sulphurets are hence liable to oxygenation from exposure to water, or to a humid atmosphere.

Sulphur combines not only with the metals, but also with their oxides. Its attraction is, however, according to Vauquelin, weaker to these than to the metals, and it becomes weaker as the degree of oxidation is greater.

Sulphuretted hydrogen displays relations to the metals somewhat similar. Its action on the metals is shewn by the tarnish it immediately communicates to their surface. It unites too with the metallic oxides, and from its attraction to them, is capable of decomposing a number of the metallic salts. The precipitates which it forms from these, sometimes result from the immediate combination of the sulphuretted hydrogen with the oxide of the metallic salt. Not unfrequently a more complicated action is exerted in their formation; the hydrogen of the sulphuretted hydrogen attracting partially, or entirely, the oxygen of the metallic oxide, while the sulphur combines with the metal, thus reduced either to a low state of oxidation, or altogether to the metallic state.. As these precipitates are usually of very dark shades of colour, sulphuretted hydrogen is the most delicate test of metallic matter. It is applied sometimes under the form of its watery solution; there are some salts, however, particularly those to the oxides of which, in a low state of oxidation, sulphur has no strong attraction, from the acid of which the sulphuretted hydrogen is incapable of separating the oxide; with regard to these, the presence of an alkali is necessary to saturate the acid to admit of the formation of a precipitate, and hence the alkaline hydro-sulphurets, or sulphuretted hydro-sulphurets, are more active tests. They not only serve, too, to discover the presence of metallic matter in general, but to detect the different metals by the various colours of the precipitates which they form.

A singular action, not yet well understood, is exerted in some metals by sulphur in combination with an alkali. The compound enters into combination by fusion with the metal, and even with those metals with which sulphur alone does not combine, as with gold; and what is still more singular, the metal is thus rendered soluble in water. The former effect appears to be owing to the alkali preventing the volatilization of the sulphur, and thus allowing a higher degree of heat to be applied, to favour its combination with the metal, than can be applied when the sulphur and metal alone are heated; the combination, too, being perhaps favoured by the affinity which may be exerted by the metallic base of the alkali. The second effect is more difficult of explanation, nor is the nature of the compound obtained in solution in the water well determined; it is uncertain whether the metal is oxidated, and whether sulphuretted hydrogen exists in the combination.

Phosphorus has relations to the metals similar, under a general point of view, to those of sulphur. From its volatility and inflammability, it cannot easily be directly combined with them, but the combination can be formed by exposing to heat a mixture of the metal with phosphoric acid and charcoal; the charcoal attracting the oxygen of the acid, and the phosphorus, as it is produced, combining with the metal. The metallic phosphurets have a degree of lustre approaching to metallic; they are usually soft, and are fusible and inflammable.

The metals enter into combination with each other by fusion. These compounds are named Alloys. They have uniformly the general metallic properties, opacity, lustre, density, &c. and generally, to a certain extent, the qualities of the respective metals of which they are composed, though these are also liable to be modified by the combination. The compounds with quicksilver are soft, or fluid, according to the proportions; they are named Amalgams. Some of these alloys are valuable from their peculiar qualities.

These combinations are not unlimited, either with regard to the metals which combine, or the proportions in which the combination is established. Some metals combine with great facility; others do not unite, as iron and lead, or iron and quicksilver. Frequently three or more metals can be brought into one combination. The facility of combining appears to be in some measure regulated by an agreement in fusibility and specific gravity, so that when the mutual affinity is weak, a considerable difference between two metals in these properties will prevent their combination. The same properties, and particularly the specific gravity, regulate to a certain extent the proportions in which they combine. These, in conformity to the law which chemical attraction observes, would be unlimited, and in the greater number of these combinations they actually are so. But in some cases they appear to be determinate, and the influence of the specific gravity in giving rise to this, is well exemplified in a fact sufficiently established, that in a mass of metallic alloy formed by fusion, and allowed to cool slowly, the upper and under parts of the mass are composed of the respective metals which form it in different proportions, the under part containing more of the heavier metal, while the lighter predominates in the portion above. The combination of metals is usually attended with a degree of condensation, though in some cases the reverse happens, there being an enlargement of volume, probably from the crystalline arrangement which the particles of the compound mass assume.

The arts of gilding, silvering, and tinning, and the operation of soldering, depend on the mutual affinities which metals exert.

The metals form no combinations with the earths. The metallic oxides and the earths, however, frequently combine by fusion, and form in general coloured glasses.

The metals are found in nature, either native, that is, in the metallic form, or mineralized, that is, combined with some other substance, by which the metallic properties are so far disguised. They are then, too, said to exist in the state of Ore. The substances with which they are most frequently combined, are sulphur, oxygen, and various acids, particularly the carbonic, sulphuric, muriatic, and phosphoric. These ores occur frequently crystallized, sometimes massive; they form, in a few cases, entire beds; more usually they are distributed in mineral veins, and are associated in these with various earthy fossils, particularly quartz, calcareous spar, sulphate of barytes, and fluor spar. When removed from their original repository, and freed, by pounding and washing, from the stony matter intermixed with them, they are subjected to calcination, fusion in contact with the fuel, and other operations variously adapted to particular ores, by which the foreign substances are separated, and the metal is reduced, and obtained sufficiently pure.

The class of metals has been subdivided into orders under which the individual metals have been arranged. There is no advantage in such subdivisions, which are all either inconvenient or imperfectly defined, and the different metals may be considered in that order in which the transitions are most easy, so as to admit of those being associated which are most strictly connected. Those of recent discovery, and which are imperfectly investigated, may be placed together, and considered after the others; and with regard to some of these the suspicion is probably well founded, that they are undiscovered alloys of known metals.

CHAP. I.

OF GOLD.

GOLD has always been placed at the head of the class of metals, and esteemed of the greatest value; a superiority which it derives from the richness of its colour and lustre, which are not altered or tarnished by exposure to air or humidity, from its high ductility and malleability, and its indestructibility by many of the operations by which the other metals are disguised or changed. It is found in nature usually native, and nearly pure; sometimes also, however, in combination with other metals, under the form of alloys, in which its more characteristic properties are nearly concealed. Gold has been supposed to exist, too, in the vegetable kingdom, a minute quantity of it, according to the experiments of Rouelle and others, being capable of being extracted from the ashes of plants.

Native gold, when loosely interspersed or diffused, is in a great measure freed from the foreign substances with which it is mixed, by placing it in a stream of water, on an inclined plane. The metallic residuum is triturated with quicksilver, until all the particles of gold are dissolved; the mercury is distilled off, the distillation being performed in iron retorts, and the gold remains, and is fused. When it is contained in other ores, the ore is roasted, to expel the volatile principles, and oxidate other metals.

that may be present, and the remaining gold is extracted by amalgamation with quicksilver, or fusion with lead. It still, as obtained by any of these methods, requires to be farther purified. This is done by the process termed Cupellation, which consists in combining the gold with a quantity of lead, and exposing the alloy to a melting heat in a vessel termed a Cupel, formed of bone ashes, and extremely porous, or in the large way, on the hearth of the refining furnace. The lead is extremely susceptible of oxidation, and at the same time it promotes the oxidation of other metals, and vitrifies with their oxides. They are thus removed; the vitrified matter is absorbed by the vessel, or is driven off by the blast of bellows as it collects on the surface, and the gold at length remains nearly pure. It can contain only silver, which is separated by the solvent power of nitric acid, forming the operation termed Quartation, or Parting.

Gold, when pure, is of a rich yellow colour, and its lustre is not impaired by exposure to air or moisture; its specific gravity is from 19.2 to 19.36; it exceeds therefore in density every metal, platina excepted; its hardness is not considerable, but its tenacity, under the forms both of ductility and malleability, is extremely great: it can be drawn into very fine wire, and in malleability it is superior to every other metal; one grain of it may be made to cover a space of 56 square inches, and in the gilding of silver wire, it has been calculated to be extended 12 times more than this.

Gold melts at 32 of Wedgewood's thermometer, and by an intense heat, as that of a powerful burning mirror, is volatilized unchanged. It was usually supposed to be incapable of oxidation from atmospheric air or oxygen gas, at any temperature, as it had often been exposed to long-continued intense heats, with the admission of the air, without suffering any apparent change. It is now, however, sufficiently established, that a very intense heat suddenly and momentarily applied causes its oxidation. This effect is produced by an electric discharge transmitted over gold leaf inclosed between plates of glass, or through a fine gold wire inclosed in a glass tube with atmospheric air; gold can even be made to burn by powerful electric sparks; it exhibits a vivid combustion in the galvanic circuit; it burns in the flame of an united stream of oxygen and hydrogen, and is even partially oxidated in the focus of a powerful burning mirror. Lastly, it suffers the same change to a certain extent by being heated with nitre, as has been established by the experiments of Mr Tennant, contrary to an opinion which had been generally received, that it suffers no change from the action of nitre. The oxide of gold is of a purple colour; it is supposed to be at the *minimum* of oxidation, and to contain not more than 5 or 6 parts of oxygen in 100. A yellow oxide is obtained from some of its saline combinations, supposed to contain in the same quantity ten of oxygen. Both these oxides are decomposed, and metallic gold obtained by a heat equal to that which is necessary to its fusion.

Gold is scarcely acted on by any of the acids. Even the nitric acid, which imparts oxygen so readily to the other metals, has scarcely any sensible effect upon it, and it is only when the acid is surcharged with nitric oxide, and boiled on the gold, that a very minute quantity is dissolved. Oxymuriatic acid, yielding oxygen more readily, dissolves it with more facility; but nitro-muriatic acid is its proper solvent. An acid, composed of two parts of nitric and one of muriatic acid, dissolves it rapidly; and even with a much smaller proportion of nitric acid the solvent power is exerted. The power of this compound acid appears to depend, not on its containing a portion of oxymuriatic acid, as has been supposed, for its solvent effect much exceeds that of the latter acid even in its pure state, but on the muriatic acid, by a resulting affinity, enabling the gold to decompose the nitric acid, and receive oxygen from it; the effect being analogous to that of muriatic or sulphuric acid dissolving a metal by enabling it to decompose water.

The solution of gold in nitro-muriatic acid, when concentrated, is of a rich yellow colour; it contains always an excess of acid, but by evaporation a salt is obtained, approaching to the neutral state, in small pyramidal crystals of the same colour. This salt is the muriate of gold; the nitric acid of the nitro-muriatic acid being either decomposed during the solution, or volatilized in the evaporation; it is deliquescent, is easily soluble in water, and likewise in alkohol and ether; it is decomposed by heat, and by light.

The other salts of gold have scarcely been examined; they may be formed by adding the gold previously oxidated to the acid with which it is designed to be combined. The nitrate and sulphate do not crystallize; the phosphate melts into a glass of a rich red colour.

The solution of gold in nitro-muriatic acid is decomposed by the alkalis. Potash and soda throw down a precipitate of a yellow colour, probably a sub-muriate; by an excess of alkali it is in part re-dissolved. Ammonia exerts a more peculiar action; it forms a precipitate, which, if an excess of alkali were added, would be re-dissolved. This precipitate is highly fulminating, and has been known by the name of *Aurum fulminans*, fulminating or detonating gold. When dry, it explodes from the application of a heat not higher than 300°, or from friction or percussion; and as a very slight degree of friction causes it to detonate, it is necessary to make experiments on it with caution; the explosion is accompanied with an acute report, and a flash of light visible in the dark, and with a considerable exertion of expansive force. It has been ascertained by experiments made with caution on small quantities of it, that in its detonation nitrogen gas is disengaged with watery vapour, metallic gold intermixed with the purple oxide remaining; if heated very gently, so as to decompose it without detonation, ammonia is exhaled; the precipitate, therefore, is a compound of ammonia and oxide of gold, and its detonation is owing to the re-action of the elements of these, the oxygen of the oxide combining with the hydrogen of the ammonia, and forming watery vapour, the nitrogen of the ammonia escaping from the combination, and the elasticity of both being augmented by the extrication of caloric which probably attends these new combinations.

Gold having a weak affinity to oxygen, its saline compounds are easily decomposed by substances which de-oxidate their base. Thus the muriate of gold is reduced by exposure to light, and by the agency of hydrogen, charcoal, and other inflammables. It is also decomposed partially or entirely by other metals; zinc, iron, and copper, throw down the gold in its metallic state; others precipitate it in the state of the purple oxide. Even some metallic salts, prepared so as to be at the *minimum* of oxidation, occasion similar decompositions. A solution of green sulphate of iron reduces the gold entirely to the metallic state, from its power of attracting oxygen. A solution of tin in nitro-muriatic acid, prepared so as to be in a low state of oxidation, throws down a purple precipitate: this is a compound of the oxides of the two metals, the oxide of tin attracting a portion of oxygen from the oxide of gold; both by this change in the state of oxidation become insoluble in the acid in which each was dissolved; and exerting at the same time a mutual affinity, they are precipitated in combination. This precipitate has been long used, under the name of *Purple Powder of Cassius*, to give a red colour to ornamental glass.

Another decomposition rather singular which muriate of gold suffers, is that from the action of essential oils, alkohol, or ether. If a portion of essential oil be mixed with its solution, the watery portion is separated, the muriate of gold combines with the oil, and this combination can be dissolved in alkohol, forming a preparation known by the name of Potable Gold, which, from its comparative mildness, has sometimes been taken internally, when gold was supposed to possess medicinal powers. From these solutions the gold is gradually precipitated in its metallic state, the oxygen of the oxide being attracted by the hydrogen of the essential oil.

Gold does not combine with sulphur by fusion, but if melted with an alkaline sulphuret, as sulphuret of potash, a combination is formed, as has already been remarked, which is soluble in water. This solution is decomposed by acids, and the gold is precipitated, whether in a metallic or oxidated state is uncertain, in combination with sulphur. The alkaline hydro-sulphurets also throw down a precipitate from the solution of muriate of gold.

Gold unites with a small portion of phosphorus, the compound is white and brittle, is fusible, and easily decomposed by heat.

With the greater number of the metals it forms alloys; those of them which are of any importance will be noticed under the history of the metals from which they are formed. In general, in these combinations, either its ductility or colour is much impaired. Copper and silver are those which change it least, and as copper renders it harder, this alloy is used for many of the purposes to which gold is applied, such as the fabrication of coin and ornamental vessels or trinkets. The standard gold of this country has an alloy of copper of one part in twelve. Lead, bismuth, and antimony, even in very minute quantity, render gold quite brittle, so that even the vapour rising from these metals in fusion, coming in contact with melted gold, has this effect. Quicksilver too renders it brittle, penetrates it rapidly, and when in sufficient quantity, dissolves it.

Gold, as the most valuable of the metals, is employed as the medium of exchange, which regulates the value of the others. It is used for many ornamental purposes under different forms. There are various modes, too, of covering the surfaces of bodies with it for similar purposes. The gilding of metals is performed in the most substantial mode, by applying an amalgam of gold and silver to the metal designed to be gilt, generally silver or copper, its surface being previously cleaned and brushed over with a dilute solution of quicksilver in nitric acid, so that a thin film of quicksilver shall be deposited on it, which favours the adherence and union of the amalgam. The quicksilver is volatilized by the application of a slow and equable heat, and the gold remains covering the surface. Other kinds of gilding on metals less substantial, are executed by rubbing the gold in a state of extreme mechanical division, on the surface of the metal heated, or by applying a solution of muriate of gold. Steel is gilt by dipping it in a solution of muriate of gold in ether. Gold leaf is applied to wood, paper, &c. by an adhesive paste: and glass and porcelain are gilded by applying gold by the medium of borax, which vitrifies with a moderate heat.

CHAP. II.

OF SILVER.

Silver is a metal, which, like gold, is rendered valuable by its colour and lustre, its great ductility and malleability, and not being liable to oxidation from exposure to the air. It is liable, however, to tarnish, by which the beauty of its colour and its lustre are diminished, a change, owing to the operation of minute quantities of sulphuretted hydrogen, diffused through the atmosphere from animal effluvia. Its comparative scarcity has added to its value, and rendered it the medium of exchange next in value to gold.

Silver is found native and mineralised: the substances by which it is usually mineralized, are oxygen, sulphur, muriatic and sulphuric acids, forming, in various states of combination and mixture, a number of ores. Native silver is extracted from the earthy matter mixed with it by washing and amalgamation, the quicksilver with which it has been amalgamated being abstracted by distillation. Its ores are subjected to various processes, principally roasting, and fusion in contact with the fuel. The metallic matter obtained is afterwards melted with lead, and refined by the process of cupellation, as has been described under the history of gold.

Silver has a colour approaching more nearly to pure white than any other metal; its lustre is considerable, and it is peculiarly sonorous, and gives, when struck, a very clear sound. In malleability it is inferior only to gold; in ductility it is equal or nearly so to that metal: it is harder and more elastic than gold; its specific gravity is 10.5.

Silver melts at 22° of Wedgwood's scale; by slow cooling it can be crystallized in octaedrons: it expands considerably in becoming solid. By a very powerful heat, it is volatilized.

Silver, as well as gold, was supposed to suffer no change from the action of atmospheric air at a high temperature. The practicability of its oxidation, however, has been sufficiently established. An electric discharge transmitted over silver leaf, or silver wire, by the high temperature it suddenly excites, gives rise to the formation of vitrified oxide; in the circuit of a powerful galvanic battery, silver leaf burns with great splendour; and its oxidation with the phenomena of combustion is effected, by subjecting it to the intense heat excited by a stream of oxygen gas, directed on burning charcoal, or mingled with hydrogen gas kindled; an oxide of a dark colour is obtained by these processes. Another of a lighter colour is obtained by precipitation from its solution in nitric acid, which, it has been stated, contains 10 parts of oxygen in 100 parts. These oxides are reduced by the operation of an elevated temperature, and the silver is obtained in its metallic form.

Silver is oxidated by several of the acids, which at the same time combine with its oxide. Nitric acid is its proper solvent; but in effecting its solution, the singular phenomenon is displayed which the same acid exhibits with regard to some other metals, and of which no satisfactory explanation has been yet given,—that when concentrated it has no sensible effect on the metal, while the addition of a very small quantity of water causes the action instantly to commence, whence the oxidation and solution of the metal proceed. The solution of silver in diluted nitric acid has at first a greenish colour; but if the silver has been pure, and in particular free from copper, this arising merely from the presence of a little nitric oxide, soon disappears, and the solution becomes colourless. By evaporation, it affords white tabular crystals, which consist of 64 of oxide of silver, 22 of acid, and 14 of water. This salt is abundantly soluble in water; it acts as a caustic very rapidly on animal matter, and fused and run into cylindrical moulds, it forms the lunar caustic of surgeons, which is in common use as an escharotic, powerful in its action, and easily applied and regulated. It is partially decomposed by heat, and likewise by light; it detonates when heated with combustible bodies, and with some of them, as phosphorus, it detonates on percussion.

The other salts of silver are obtained most easily by adding to the solution of nitrate of silver a solution of a neutral salt, containing the acid with which the oxide of silver is designed to be combined. Thus the sulphate is formed by adding to the solution of nitrate of silver, a solution of sulphate of potash or soda. It is also formed by boiling the sulphuric acid on silver, the acid being decomposed at this temperature, communicating oxygen to it, and combining with the oxide. The sulphate of silver is very sparingly soluble in water; by boiling water upon it, a minute quantity is dissolved, and slender crystals are obtained by cooling.

Muriate of silver can scarcely be obtained from any action of muriatic acid on metallic silver, but it is instantly formed on the addition of the solution of any muriate to the solution of nitrate of silver, and being insoluble, is precipitated. From the extreme insolubility of this salt, it is the re-agent of greatest delicacy in detecting the presence of muriatic acid. It affords also the most delicate test of the chemical agency of light, being blackened by exposure for a few minutes to the rays of the sun. It is very fusible, melting on the application of a moderate heat in a glass matrass; on becoming solid from cooling, it retains a degree of transparency, is of a pearly colour, is soft, and to a certain extent malleable and fusible; whence, from its resemblance in these properties to horn, it received from the older chemists the name of Luna Cornea, or Horn Silver. By exposing it to a strong heat, it is decomposed; both the acid and oxygen are expelled, and the silver is recovered in its metallic form. The reduction is favoured by the presence of a small portion of alkali; one part of the sub-carbonate of potash is added to four parts of the muriate, the mixture being exposed to a red heat in a crucible, or rather in a phial within a crucible, surrounded with sand; and this affords the best process for obtaining pure silver.

Oxymuriatic acid acting on silver, communicates to it oxygen, the muriatic acid uniting with the oxide so as to form merely the common muriate. A hyper-oxymuriate of silver can be formed, however, by transmitting a current of oxymuriatic acid gas through water in which oxide of silver is diffused. This salt is abundantly soluble in water, and crystallizes in rhombs; it is also soluble in alkohol. It is melted and decomposed by heat. It detonates by percussion with inflammable bodies.

Phosphate of silver is insoluble in water, and is hence precipitated copiously when a solution of phosphate of soda is added to a solution of nitrate of silver. Carbonate of silver, obtained by the addition of an alkaline carbonate in a similar manner, is likewise sparingly soluble; as are the fluate and borate of silver. The carbonate is blackened by light, and is decomposed by heat, affording metallic silver.

The salts of silver are decomposed by the alkalis and earths. From nitrate of silver, potash throws down a yellowish precipitate, probably a sub-nitrate; and the action of soda and lime is similar. The precipitate from the addition of ammonia is grey or black, but it has not, like the precipitate from the solution of gold by ammonia, any detonating power.

A fulminating silver can be prepared, however, which far exceeds the fulminating gold, or indeed any other fulminating preparation, in power. The process was given by Berthollet; it consists in dissolving silver in nitrous acid, diluted with three parts of water; to the solution, poured off from any undissolved matter, lime-water is added as long as any precipitation is occasioned, avoiding any excess of it; the precipitate is washed with distilled water, and dried by exposure to the air. This precipitate is stirred in liquid ammonia; the liquor is poured from the insoluble matter; on exposure to the air, a pellicle forms on its surface which at length subsides. This is the fulminating silver; such is its tendency to explosion, that it cannot be touched, the slightest impulse or agitation causing it to detonate; and so violent is the detonation, that the experiment cannot be made with safety on a quantity larger than a grain. The theory of its detonation is considered as similar to that of fulminating gold: it probably consists of oxide of silver and ammonia, the whole elements being united by affinities so nicely balanced, that the slightest external force subverts them, and causes new combinations: the oxygen of the oxide unites probably with the hydrogen of the ammonia, and forms watery vapour: the nitrogen must at the same time assume the elastic form, and the augmentation of elasticity in these products, by the caloric suddenly extricated, may be the cause of the violence of the detonation. The superiority of this preparation in detonating power to fulminating gold, may be owing to the oxide of silver containing a larger proportion of oxygen, and combining with a larger quantity of ammonia, so that there are condensed in the fulminating silver, a larger quantity of the elements disposed to enter into the combinations whence these elastic products are evolved.

Another fulminating silver is prepared by a process similar to one by which a fulminating quicksilver is prepared, to be afterwards described; but it is considerably inferior in detonating power.

The salts of silver are decomposed by inflammable substances, and by the greater number of the metals, the oxygen being attracted from the oxide, which is their base, and the silver precipitated in the metallic form. Among the metals, copper and quicksilver produces this precipitation with great facility, probably from the mutual affinity exerted between the precipitating and the precipitated metal. Copper is thus employed to recover silver from its solution in nitric acid, as a mode of obtaining it free from other metals, the small quantity of copper with which the precipitated silver may be alloyed, being removed by cupellation. Quicksilver employed in a peculiar manner in the precipitation of silver, causes its crystalline arrangement, similar in appearance to arborescence, hence forming what has been named Arbor Diannæ. The simplest mode is to dissolve along with the silver half its weight of quicksilver in nitric acid, and to drop into this solution, diluted with forty-eight times its weight of water, a small piece of a soft amalgam of silver; filaments of reduced silver soon shoot out from the amalgam.

Silver combines by fusion with sulphur, forming a compound of a very dark violet colour, with a certain degree of metallic lustre, opaque, soft, and brittle. Sulphuretted hydrogen tarnishes silver very rapidly, and from its continued action, thin scales of sulphuret of silver are formed. A precipitate probably of a similar nature is thrown down from the salts of silver, by the hydro-sulphuretted alkaline solutions. The alkaline sulphurets, fused with silver, form a compound soluble in water, from which the acids precipitate sulphuret of silver.

Silver and phosphorus may be combined by the general process which has been already described, as affording the easiest mode of uniting phosphorus with the metals. This phosphuret is white, of a granular structure, soft and brittle.

Silver unites with the greater number of the metals, suffering in general a diminution in its ductility and malleability, but acquiring frequently a greater degree of hardness. It unites with gold without any loss of ductility, while it communicates to the gold hardness and elasticity; when in a large proportion, however, it debases its colour. When the silver amounts to one-fifth of the mass, the colour is green, and this alloy is used for ornamental purposes. The alloy of gold and silver being more fusible too than gold, is employed in soldering this metal. Copper added in small proportion to silver, renders it harder without much impairing its ductility, and hence this addition is usually made when it is to be fabricated into coin or plate. The standard silver of this country contains one-sixteenth of copper.

Silver is used as the medium of exchange next in value to gold, and is applied to ornamental purposes, to which it is well adapted by its lustre, and the purity and beauty of its colour. It is applied to the surface of other metals in various modes. The most substantial plating is a mechanical operation; a thin plate of silver being applied to a bar of copper, with a little borax between them to facilitate their union, when a sufficient heat is applied; the bar is afterwards passed through the rolling press; it is extended, and the silver, from its greater malleability, is likewise extended so as to cover the surface of the copper. Other modes are, to apply an amalgam of silver to copper, driving off the quicksilver afterwards by heat, or by rubbing on the surface mixtures of oxide or muriate of silver with muriate of soda, or ammonia, or supertartrate of potash, and applying heat so as to favour the reduction of the silver on the surface of the copper, and its adhesion on it. The silver is recovered from its intermixture with copper, by boiling them in sulphuric acid, the sulphate of copper which is formed being removed by washing, the sulphate of silver remaining insoluble; or by substituting for sulphuric acid, a mixture of it with nitric acid, or, what is more economical, with nitre; this mixed acid dissolving silver without dissolving copper.

The solution of nitrate of silver is used in analytic chemistry, to discover the presence of muriatic acid in any state of combination. Largely diluted, it forms what is named indelible ink; employed in marking linen which is to be bleached, lines traced with it becoming dark on exposure to light.

CHAP. III.

OF PLATINA.

THIS is a metal of modern discovery, the produce of the mines of Peru, and occurring always in the native state, generally in small grains of metallic lustre, a greyish white colour, ductile and malleable, and having a specific gravity not less than 17. It is mixed with various earthy and metallic fossils, and is alloyed with a small quantity of iron, so as to be sensibly magnetic. But besides these foreign substances, it has within these few years been discovered, that there occur with the metal to which the name of platina is still appropriated, others not previously known; and the existence of not less than four distinct metals has been supposed to be established by these researches. The history of these may be delivered after the history of platina itself.

It is to be remarked, however, in proceeding to the history of this metal, that if the conclusions with regard to the existence of these other metals be just, the properties of platina in a state of purity are not exactly known; for in any process which has been employed to obtain it from its native state, though they may be in part abstracted, it must retain an alloy of one or more of them to a greater or less extent.

Platina in its native form is so infusible, that the grains can scarcely be agglutinated by the application of even the most intense heat; other methods therefore are necessary to obtain it in the state of a metallic mass. The one which has been usually followed, is to dissolve crude platina in nitro-muriatic acid; on adding to this solution a solution of muriate of ammonia, a precipitate is thrown down, consisting of the oxide of platina in combination with portions of muriatic acid and ammonia: on urging this precipitate with a fire gradually raised to an intense degree, the acid and the ammonia are expelled, the oxide is reduced, and a spongy metallic mass obtained, which, by pressure or percussion while at a red heat, is rendered more dense. The metal in this state is still, however, in general so imperfectly agglutinated, and it is at the same time so infusible, as not to be easily worked. It is therefore subjected to other methods. One of the most practicable in the large way, is to alloy it with arsenic, by whch it is rendered so fusible as to be easily cast into bars, and the arsenic being afterwards volatilized by exposure to a fire gradually raised, until the platina is obtained malleable. Another is, to combine the spongy metallic platina with quicksilver; the solid amalgam is moulded when soft in bars, it quickly becomes hard, and is afterwards exposed to a heat under a muffle sufficient to dissipate the quicksilver. It is then strongly ignited, until it is sufficiently ductile to admit of being laminated and forged. It is obvious that, as obtained by any of these methods, it must be alloyed to a certain extent with the metals naturally associated with it.

Platina, in the dense state into which it is brought by the usual processes, is of a white colour, with a slight shade of grey, with metallic lustre: in hardness it is superior to the greater number of the metals; it is very malleable, though its hardness prevents it from being easily extended in leaves; it is highly ductile, and can be drawn into very fine wire. Its specific gravity exceeds that of the other metals; and hence it is the heaviest known substance; the specific gravity has been estimated from 20.8 to 24; and it must vary according as it has been more or less hammered, and as it is more or less alloyed. It suffers less expansion from heat than the other metals in general do, and it is also inferior to them in conducting power.

Platina is a metal extremely infusible. The point at which it melts exceeds that at which the pyrometrical pieces of Wedgewood cease to contract, and cannot therefore be exactly estimated; it has been supposed to be higher than 150, or even 160, of the scale of this pyrometer. By the aid of fluxes, as of borax, its fusion may be effected with more facility. It so far partakes of the property of welding, otherwise peculiar to iron, as to soften, while at the same time it remains ductile at a heat much inferior to that necessary to melt it; whence two pieces of it by forging can be united firmly together.

Platina is not very susceptible of oxidation. Its lustre suffers no diminution from exposure to air or humidity; nor does it lose its metallic qualities when exposed even to intense heats, with the admission of atmospheric air. By a very intense heat, however, suddenly applied, as that from the discharge of an electrical battery, by which it is not only fused but volatilized, it is oxidated. It suffers also oxidation from the action of nitre at a high temperature. Mr Chenevix endeavoured to estimate the proportion of oxygen in the oxides which exist in its saline compounds. Having decomposed the nitrate of platina by heat, he obtained an oxide of a yellow colour, which by a higher heat was reduced to the metallic state. This oxide, he concluded, consists of 87 of metal and 13 of oxygen. In the progress of its reduction, it assumed at one stage of the process a green colour, remaining so for some time. This he supposed to denote a different degree of oxidation, and the proportion of oxygen in this green oxide he estimated at 7 in 100 parts.

Platina is scarcely acted on by any of the acids, but the nitro-muriatic, and the oxy-muriatic: even nitric acid boiled on it, does not change its lustre. Nitro-muriatic acid is its proper solvent, and the muriate afforded by this solution is the only salt of this metal that has been particularly examined. When the acid is composed of three parts of muriatic, and one of nitric acid, it dissolves the largest proportion of the metal: as the mutual action proceeds, a black powder is deposited, which consists principally of some of the foreign metals contained in native platina. The solution is of a dark reddish-brown colour, and by evaporation it affords crystals of the same colour, but usually of various shades.

This solution is decomposed by the alkalis; when a solution of potash is added, in a short time small reddish octohedral crystals are deposited; if an additional quantity of alkali be afterwards added, a yellow flocculent precipitate is thrown down. Ammonia gives rise to similar results. Soda throws down only the yellow precipitate. These precipitates are ternary compounds of oxide of platina, with a portion of muriatic acid, and of the alkali by which the precipitation has been produced; there being also present in their composition, a small quantity of one of the metals associated with native platina, as is immediately to be stated.

From the nature of these precipitates, they are likewise formed by adding to the solution of muriate of platina, a solution of a neutral salt containing these alkalis. Thus precipitates are formed by muriate of potash, or muriate of ammonia, and even by the sulphates or nitrates of these alkalis. This kind of precipitation of the solution of platina by a neutral salt containing the same acid, as the acid of the solution, being rather uncommon, has been frequently the subject of investigation with chemists, the facts with regard to it were found difficult of investigation, and it is only lately that they have been elucidated.

From the addition of muriate of ammonia to a solution of platina in nitro-muriatic acid, it was known that precipitates were successively thrown down of different shades of colour, being at first of a light yellow, becoming afterwards deeper, and at length of a reddish-brown. These were supposed to arise from different degrees of oxidation, but it has been established by the experiments of Descostils, and of Fourcroy and Vauquelin, that the difference arises from the presence of one of the metals associated with native platina, that which has been named iridium: the red precipitate is a ternary combination of the oxide of this metal with muriatic acid and ammonia; the yellow precipitate is that which platina, apart from this metal, gives from the action of muriate of ammonia; and it too is a ternary compound, being composed of portions of the acid and alkali with the oxide of platina. The black powder, which separates during the solution of crude platina in nitro-muriatic acid, consists principally of this iridium; and the more perfectly it has been separated, the colour of the red precipitate produced by the addition of muriate of ammonia to the solution is less intense; and it is to the same substance that the dark colour of the crystals obtained by the evaporation of the solution of platina is owing. It is only from the yellow precipitate, submitted to reduction by the application of heat, that platina pure, or at least free from iridium, can be obtained.

The solution of muriate of platina is decomposed by several of the metals and metallic salts, which de-oxidize it partially or entirely. Muriate of tin is, by an action of this kind, a very delicate test of it, a bright red colour being assumed when a few drops are added to the solution of platina, diluted with a very large quantity of water. It is not precipitated, as the greater number of metallic salts are, by prussic acid, or the prussiates.

Platina and sulphur do not unite by fusion, owing probably to their weak mutual affinity, and the extreme infusibility of the metal. It combines, however, with the alkaline sulphurets; and sulphuretted hydrogen added to its solution causes a precipitation.

It combines with phosphorus; the compound is of a silvery-white colour, brittle and very hard; it is fusible, and when urged by a strong heat, is decomposed, the phosphorus being expelled; hence the combination with phosphorus has been employed as a method of rendering platina fusible and capable of being worked.

Platina combines with the greater number of the metals; but our knowledge of its real alloys is altogether imperfect, from platina, as hitherto employed in these combinations, having been used alloyed more or less with the metals with which it is naturally associated. With gold an alloy is formed of a yellowish-white colour, highly ductile and elastic, and of a specific gravity of 19. The alloy with silver is of a dull colour, and harder than pure silver. With quicksilver platina was supposed not to combine, but the amalgamation can be effected when the platina is in that spongy state in which it is procured by the decomposition of the ammoniaco-muriate by heat.

Platina is a metal of considerable value, from its hardness, its infusibility, and not being liable to be acted on by the greater number of chemical agents. It is from these qualities adapted to many chemical purposes, and hence is employed in the construction of tubes, evaporating basons, and crucibles, and in the form of wire for galvanic experiments. From its infusibility, it is adapted by its expansion to measure high temperatures, and it has accordingly been applied as a pyrometer. From its property of suffering less expansion than other metals from heat, and not being liable to rust, it is superior to others for the construction of the pendulum-spring of watches. Other metals, copper for example, can be covered with a coating of it, by applying an amalgam prepared from the trituration of the spongy platina with five parts of quicksilver, to the surface of the copper, and applying heat so as to favour the volatilization of the quicksilver, and the adhesion of the platina. Brass or steel may be coated with platina by a process similar to that by which they are gilded,—adding sulphuric ether to a solution of platina; removing the etherial solution from the acid liquid beneath it, and dipping into this the polished steel or brass. Platina has also been applied to porcelain-painting, by means of the flux by which gilding or painting is effected, and serves to diversify the painting with gold.

CHAP. IV.

OF IRIDIUM.

THIS is the first of the metals which, it has been stated, have been lately discovered to exist in native platina; and of which, as our knowledge is still imperfect, and their claims to the rank of distinct metals are not altogether certain, it will be sufficient to give a general account, without much minuteness of detail.

Iridium constitutes the principal part of the black powder which is deposited during the solution of the grains of native platina in nitro-muriatic acid, and which, in part dissolved, communicates to the solution and the crystals it affords by evaporation, a red colour. It may therefore be obtained, either from the black powder, or from the dark red precipitate which is thrown down from the solution, by the addition of muriate of ammonia, and which consists chiefly of the oxide of this metal, with portions of ammonia and muriatic acid.

It is obtained from the precipitate by the action of heat alone, the acid and ammonia being expelled, and the oxide reduced; the black powder affords it with the same facility: when heated merely before the blow-pipe, it loses its black colour, and becomes white, and acquires metallic lustre: when fused with borax, it forms white metallic scales. In this state, however, the metal is not perfectly pure, it has an alloy of iron, and of another metallic substance, which Vauquelin supposed to be chrome, but which Tennant has inferred is a new metal, which he has named Osmium. To obtain the iridium free from these, more complicated processes are necessary, consisting primarily in subjecting the black powder to the alternate action of potash in fusion, and muriatic acid; the alkali dissolving the other metals, the acid dissolving the iridium with a portion of iron. From the muriatic solution, the iridium may be obtained, by precipitating it in its metallic form, by immersing plates of zinc in the solution; or by evaporating the solution to dryness, removing the muriate of iron by alkohol, and afterwards reducing the muriate of iridium by exposure to heat; or lastly, simply by evaporating the muriatic solution to dryness, dissolving it again in water, and by a second operation, obtaining from it octaedral crystals; these, by exposure to heat, afford iridium.

This metal is of a white colour, brittle, hard, and easily reduced to powder; it is fused and volatilized by heat, it is also oxidized; by applying a strong heat to crude metallic platina in an earthen retort, a sublimate of a blue colour is obtained, which is oxide of iridium; or by calcining the metal with potash, its oxide is formed by the action of the air, and combines with the alkali. In its saline combinations, it also displays phenomena, which appear to prove its existence in different states of oxidation. Thus the solution of it in muriatic acid, is of a deep green colour: by mere dilution with water, it becomes blue; when heated it becomes red; and when in this state it is submitted to the action of substances capable of deoxidating it, the red colour is removed, and the green or blue restored. It is from these changes of colour, which are characteristic of this metal, that Mr Tennant named it Iridium.

Iridium, in its metallic state, is scarcely acted on by any acid; even the nitro-muriatic acid, with the assistance of heat, dissolves a very small portion of it: it is more soluble when alloyed with platina. When it has been oxidated by exposure to the air, aided by the action of potash at a high temperature, it dissolves easily in the acids; the solution in nitric acid is of a red colour; in sulphuric or muriatic acid it is green or blue, according to the state of dilution: the alkalis throw down from these solutions precipitates of the same colour. The greater number of the metals give rise to a dark-coloured precipitate, and remove the colour of the solution. Sulphuretted hydrogen has a similar effect.

This metal does not unite with sulphur by fusion. It combines with some of the other metals; both gold and silver alloyed with it remain malleable; the iridium is not separated by cupellation, but only by solution in nitro-muriatic acid.

CHAP. V.

OF OSMIUM.

In submitting the black powder which is precipitated during the solution of native platina in nitro-muriatic acid, to the action of potash or soda, at a high temperature, the metallic matter is oxidated; and while one portion of it becomes soluble in muriatic acid, another portion of it enters into union with the alkali, forming a compound which is soluble in water. The latter Mr Tennant has regarded as the oxide of a new metal, to which, from the strong smell it has in its oxidated state, he has given the name of Osmium.

Th oxide of osmium, obtained in combination with the alkali by the above process, is separated by the addition of an acid; and, what is a very singular property, it can be obtained in solution in water by distillation. The solution is limpid, has a sweetish taste, and a pungent peculiar smell. It does not redden the vegetable colours, but paper stained with the colour of violet, exposed to the vapour arising from it, loses much of its blue tinge, and becomes grey. This oxide is obtained in a more concentrated state, by distilling the black powder from crude platina with nitre; a fluid of an oily appearance distils over, which on cooling forms a colourless semi-transparent solid mass, soluble in water. This concentrated solution stains the skin of a dark colour.

Oxide of osmium parts with its oxygen without difficulty. It becomes black when diffused in alkohol or ether, and soon separates in black films. The greater number of the metals deprive its solution speedily of smell, and a black or grey oxide is precipitated, consisting of the osmium in a metallic state, with the oxide of the metal by which it has been precipitated. If quicksilver be employed to precipitate it, an amalgam is obtained; by applying a sufficient heat the quicksilver is volatilized, and a powder remains, of a dark grey or blue colour, which is metallic osmium. This is the process by which Mr Tennant procured it. The metal he found not to be very fusible nor volatile; exposed to a strong white heat in a cavity in a piece of charcoal, it was not melted, nor did it suffer any apparent alteration. When heated in a similar manner with gold, or with copper, it melted, and formed alloys with these metals. When heated with the access of air, it is oxidated, and the oxide evaporates, diffusing its peculiar smell.

In its metallic state, osmium does not appear to be acted on by the acids, not even by the nitro-muriatic acid. By exposing it to heat with potash it is oxidated, and enters into combination with the alkali, forming a compound soluble in water, from which the oxide may be precipitated by acids.

A striking property by which this metal in its oxidated state may be recognized, is displayed in the action of infusion of galls upon it. Added to its solution, it produces a purple colour, which soon becomes of a vivid blue. The solution of oxide of osmium become yellowish, on the addition of pure ammonia, or of carbonate of soda; and a bright yellow is acquired from the action of lime. The peculiar smell, and the volatility of this oxide, are still more characteristic, and undoubtedly distinguish it from every other substance.

CHAP. VI.

OF RHODIUM.

Dr Wollaston, submitting to examination the liquid which remains after the precipitation of the solution of crude platina in nitro-muriatic acid by muriate of ammonia, found reason from his experiments to conclude, that it contained two new metals, one which he named Rhodium, the other Palladium. The following is the process by which these were separated, and the present metal, rhodium, obtained.

Crude platina, having been dissolved in nitro-muriatic acid, was precipitated by muriate of ammonia. In the remaining liquid, to which the water with which the precipitate was washed was added, a piece of zinc was immersed, until no farther action appeared to be exerted on it. The iron contained in the crude platina remained in solution: the other metals had been precipitated in a black powder, estimated to amount to betweeen 40 and 50 grains. This precipitate, which by previous experiments was known to consist of platina, rhodium, palladium, copper, and lead, was digested in very dilute nitric acid, by which the two latter metals were removed. The remainder was digested in nitro-muriatic acid, which dissolved the greater part. To the solution was added 20 grains of common salt; and when the whole had been evaporated to dryness with a gentle heat, the solid matter, consisting of the triple salts of soda and muriatic acid, with oxide of platina, of palladium, and rhodium, was washed repeatedly with alkohol, till it came off nearly colourless. There remained undissolved the triple salt of rhodium, which is thus freed from all metallic impurities. When dissolved in water, and decomposed by zinc, a black powder was obtained, in quantity corresponding to about 4 grains from the 1000 grains of crude platina dissolved. This powder, exposed to heat, continued black; with borax it acquired a white metallic lustre, but appeared infusible by any degree of heat. Like platina, it is rendered fusible by arsenic, as it also is by sulphur: the arsenic, or the sulphur, is expelled by a continuance of the heat; but the metallic button obtained does not become malleable. Its specific gravity, as far as could be ascertained, appeared to exceed 11.

From the triple salt of oxide of rhodium, soda, and muriatic acid, the pure alkalis throw down a yellow oxide, which is dissolved by adding an excess of alkali. It is also soluble in the acids; its solution in muriatic acid does not crystallize by evaporation; muriate of ammonia or of soda causes no precipitation from it; the solution in nitric acid also does not crystallize; the rhodium is precipitated from it by silver, copper, and other metals.

Rhodium unites with all the metals, quicksilver excepted. Its alloys with gold and silver are malleable; the colour of gold is little altered, even when the rhodium amounts to one-sixth of the mass. In dissolving it in nitro-muriatic acid, the rhodium remains undissolved.

The properties assigned to this metal are not very distinctive, and it is not very improbable that it may be an alloy of some of the others.

CHAP. VII.

OF PALLADIUM.

This metal exists with rhodium in the liquor remaining after the solution of native platina has been precipitated by muriate of ammonia; and in the process already described under the history of rhodium, it has been remarked, that the soda-muriate of palladium being soluble in alcohol, while that of rhodium is insoluble, they are thus separated from each other. To the solution of the former salt, muriate of ammonia is added to precipitate any platina that may be present. There is then added to it prussiate of potash, which throws down a precipitate of a deep orange colour. This dried and exposed to heat affords a metallic residuum, which, when heated with borax, acquires metallic lustre, but does not melt before the blowpipe; a little sulphur added to it causes its fusion: from the globule thus obtained, the sulphur is expelled by urging it with the flame, and a spongy malleable mass remains. Dr Wollaston, the discoverer of this metal, has given other processes to procure it. One of the most simple is, to add to a solution of crude platina a solution of prussiate of mercury; a occulent precipitate of a yellowish colour gradually accumulates; this is prussiate of palladium, and when decomposed by heat, it affords the metal in a pure state.

Palladium is of a greyish-white colour, and when polished has considerable lustre; it is ductile and very malleable; in hardness it is superior to forged iron; its specific gravity is from 11 to 11.8; like platina, it is less expansible, and is a less perfect conductor of heat, than the greater number of the metals. It requires a heat of a considerable intensity to fuse it. Heated under exposure to the air, it is not oxidated, and its oxides obtained by other methods are reduced by heat.

This metal is acted on by a number of the acids. Nitric, sulphuric, muriatic, and nitro-muriatic acids, acquire from it a rich red colour, and dissolve a portion of it. These solutions are decomposed by the alkalis and earths, precipitates of an orange colour being thrown down, which are partly re-dissolved if the alkali is added in excess. The sulphate, nitrate, and muriate of potash, or of ammonia, produce precipitates likewise of an orange colour from the saturated solutions of the salts of palladium, which are triple salts.

The alkalis act on palladium even in its metallic state. Exposed to the action of melted potash, it loses its lustre and part of its weight, and part of the metal is oxidated and combined with the alkali. Ammonia digested on it acquires a bluish tinge, and holds a small portion of oxide in solution, the oxidation in these cases being formed by the action of the air.

All the metals, with the exception of gold, silver, and platina, precipitate palladium in its metallic state from its saline solutions. Green sulphate of iron also throws it down. Muriate of tin forms a precipitate of a dark orange or brown colour; sulphuretted hydrogen gives a precipitate of a dark brown colour; prussiate of potash one of an olive colour; prussiate of mercury, a precipitate of a yellowish white colour; and as this re-agent does not precipitate platina, this affords a very good test to distinguish between these metals. This precipitate by prussiate of mercury from the nitrous solution of palladium explodes when heated to 500° of Fahrenheit.

Palladium combines with sulphur, and is instantly fused when sulphur is thrown upon it at a high heat. The sulphuret is white and brittle.

It forms combinations with a number of the metals. Its alloy with gold is of a grey colour, harder than gold, but less ductile even than the palladium. Its alloy with silver is likewise grey and hard. Platina and palladium enter into fusion at a heat not higher than that at which palladium itself melts, and an alloy is formed similar to the preceding in colour and hardness. Its other alloys are likewise in general hard and brittle.

Palladium had been supposed by Mr Chenevix to be an alloy of platina and quicksilver; and there are some facts established by his experiments, and those of some other chemists, which prove that these two metals, by combination, modify very powerfully the properties of each other, and acquire even some of those characteristic of palladium, particularly that of being precipitated in the metallic state by sulphate of iron. The synthetic experiment of the formation of palladium has not succeeded, however, with other chemists; no analytic experiment has been successful in establishing its composition, and its properties appear to be sufficiently characteristic to entitle it to be ranked as a distinct metal. This interesting discovery is still farther confirmed by that lately made by Mr Cloud, that it exists apart from platina, forming a native alloy with gold; and Dr Wollaston has also observed it in a distinct form in the grains of native platina.

CHAP. VIII.

OF QUICKSILVER, OR MERCURY.

THIS is distinguished from all the metals by its perfect fluidity at common natural temperatures: it becomes solid at —39° of Fahrenheit, and has then considerable malleability. In its liquid state it is perfectly opaque, and has the metallic lustre; its specific gravity is 13.5. In passing to the solid state it suffers considerable condensation, equal, as has been calculated, to $\frac{1}{23}$ of its volume: this gives its specific gravity in the solid state, at 14.17; by actual experiment, it has been found to be 14.46. In its congelation, it assumes a crystalline structure, and it can even be obtained in small octaedral crystals.

Quicksilver occurs native in small quantity. Its usual state is mineralized by sulphur; and from this ore it is extracted by distillation, the separation from the sulphur being facilitated by the intermedium of lime or iron. It is also purified by distilling it a second time from a portion of iron filings.

The temperature at which quicksilver is volatilized under a middle atmospheric pressure, is between 600° and 700° of Fahrenheit, being stated on different authorities at 655°, 660°, and 672°.

At the same temperature as that at which it is volatilized, it is oxidated by the action of atmospheric air. When kept boiling gently, its lustre diminishes, a film forms on its surface, and small scales of a brick-red colour accumulate, the oxygen of the air being at the same time absorbed. The operation is not easily conducted without loss from the volatilization of the mercury; but it is best performed in a glass matrass, with a shallow bottom, and the neck drawn out to a small aperture, a small quantity only of quicksilver being put into it, and the heat being applied steadily by a sand-bath. This red oxide contains

7 of oxygen in 100 parts; it is reduced by the heat of ignition to the metallic state.

There is also reason to conclude, that quicksilver is susceptible of oxidation, even at natural temperatures. It is to be regarded as a metal in a state of fusion; and in this state, the cohesion being so much diminished, the greater number of the metals combine with oxygen. From quicksilver, by agitation continued for some time, a grey powder is obtained, which some have regarded as the metal mechanically divided, but which it is more probable is an oxide, as it is soluble in muriatic acid, which quicksilver is not. This oxidation appears to be effected with more facility, when the continuity of the quicksilver is interrupted, and its surface extended by the interposition of any viscuous matter, as mucilage, honey, or fat; and in this way are formed a number of medicinal preparations, the efficacy of which depend on this oxide. The proportion of oxygen in its composition has been estimated at 4 in 100 parts.

Besides these oxides, it appears to be proved, that mercury exists in other degrees of oxidation in its saline combinations; though the precise proportions are not easily determined. Thus there are two muriates of mercury, differing in the degree of oxidation. The oxide in one of them, Mr Chenevix inferred, contains 15 of oxygen in 100 parts, that in the other 10.7. Another chemist, Zaboada, has more lately inferred, that the oxide in the former contains not more than 10 parts, and that in the latter little more than 5 in 100 parts. The degrees of oxidation in the solutions of the metal in nitric acid, appear to be more numerous, and probably even indefinite.

The greater number of the acids act on quicksilver, or at least are capable of combining with its oxides.

Sulphuric acid exerts little action upon it in the cold, but if heat be applied it is decomposed, the quicksilver is oxidated, sulphurous acid is disengaged, and the oxide combines with the remaining acid. The combination is different according to the proportions of acid and metal applied, and the degree of heat and its continuance. In general, it has an excess of acid, and even with this excess it crystallizes in slender prisms, thus forming a mass, soft, and partly liquid, composed of these crystals. This saline mass is very acrid, deliquescent, and soluble in water. If washed with water, a considerable part of the acid is removed, holding combined with it a portion of oxide; and the neutral sulphate at length remains, less acrid, and much less soluble in water, but which is still so far soluble as to afford by evaporation prismatic crystals. It consists, according to Fourcroy's analysis, of 75 of mercury, 8 of oxygen, 12 of acid, and 5 of water. These combinations are liable to diversity, too, not only from the proportion of acid, but also from the degree of oxidation of the metal, according to the manner in which they have been effected.

If any of these sulphates of mercury be urged with a heat gradually raised until the mass becomes dry, the metal is more highly oxidated, and the excess of acid is entirely dissipated. On pouring on this dry mass boiling water, it acquires a lively yellow colour, forming a preparation which has been long known by the appellation of

Turbith Mineral, now named Yellow Sub-sulphate of Mercury. The water in this process produces the usual effect which it has when it decomposes metallic salts. Exerting a stronger attraction to the acid than to the metallic oxide, it combines principally with the former; still, from the influence of quantity on chemical affinity, the acid carries with it a portion of the oxide, and conversely from the operation of the same force, the oxide which is precipitated, retains a portion of the acid combined with it; the neutral sulphate is thus resolved into a supersulphate which the water dissolves, and a subsulphate which remains undissolved. The quantity of the latter is greater as the acid has been more completely expelled by the previous application of heat. It is necessarily liable to be variable in its composition; it consists of from 76 to 84 of mercury, with from 10 to 15 of sulphuric acid. As a mercurial medicinal preparation, it is harsh and uncertain in its operation, and is therefore seldom used.

Sulphate of mercury suffers decomposition from the action of the alkalis and earths, precipitates of various shades of yellow and grey being formed, all of them probably sub-sulphates. Ammonia re-acts on the precipitate, and forms a ternary compound, which may be obtained crystallized, and which, according to Fourcroy's analysis, consists of 39 of quicksilver, 33 of ammonia, 18 of sulphuric acid, and 10 of water.

Nitric acid acts on quicksilver with great facility, oxidating it, and combining with the oxide, forming a perfect solution. The product of this action varies, however, considerably, particularly with regard to the state of oxidation, according to the circumstances under which it is exerted.

If the acid is diluted with rather more than an equal part of water, and if no heat is applied to accelerate the solution, the metal attracts a small portion only of oxygen, and in this imperfectly oxidated state, combines with the acid. If the acid is less diluted, and if the action of the metal on it be promoted by heat, a compound is formed with the oxide at a higher degree of oxidation. Both these solutions, when concentrated, crystallize, a mass being deposited, consisting of a congeries of slender prisms. Both salts are corrosive, deliquescent, soluble in water, and their solubility is so much increased by heat, that on applying a moderate warmth, they dissolve.

In these combinations, there is no reason to suppose that determinate degrees of oxidation are established; there appears to be a series of compounds in which the metal is oxidated indefinitely from the *minimum* to the *maximum*, and hence the solution is liable to variation from the slightest diversity of circumstances. The compound at the *maximum* of oxidation, is not easily obtained by the action of nitric acid on metallic mercury, but is formed by the direct combination of the oxide and acid. It is obvious, too, that these combinations may be diversified from an excess or deficiency of acid. In general, the acid is in excess, and it always is so when the mutual action has been exerted in the cold; and this excess of acid renders the compound more soluble, and more susceptible of dilution with water without decomposition. If the acid is boiled on the metal, the solution has at length an excess of oxide, and is incapable of dilution with water without decomposition, a sub-nitrate sparingly soluble being precipitated; while a portion of the combination approaching to the state of the neutral compound remains dissolved.

Nitrate of mercury is decomposed by the alkalis and earths, and in these decompositions are well displayed the differences which arise from the different states of oxidation of the metal. Potash, soda, or lime, added to the solution, in which the metal is at a low degree of oxidation, throws down a precipitate of a greyish colour, with a tinge of yellow; when added to the solution in which the metal is at a high degree of oxidation, the precipitate is yellow, more or less bright; and between these are precipitates of various shades, according to the state of the mercurial solution. All these precipitates are sub-nitrates, the oxide separated by the alkali retaining a portion of the acid combined with it.

The action of ammonia on these solutions is more peculiar. From the solution containing the mercury at a high state of oxidation, it throws down a white precipitate, which is a ternary combination of the oxide with portions of the acid and alkali; the proportions, according to Fourcroy's analysis of it, being 68.2 of oxide, 16 of ammonia, and 15.8 of acid and water. From the solution in which the metal exists at the minimum of oxidation, it throws down a precipitate of a dark grey or blue colour; and between these, precipitates of various shades of grey may be obtained, according as the mercury is more or less highly oxidated.

The grey precipitate (*Oxidum Hydrargyri Cinereum* of the Pharmacopœias) is a preparation much used in medicine; and it is of importance, therefore, to have it unform. The directions given for obtaining it have often been imperfect, from the theory of the process not being well understood. The whole depends on the state of oxidation of the mercury in the solution; if it be at the *minimum*, the dark grey precipitate is formed; if it is at any higher degree, then a portion of the ternary white precipitate is formed, which mingling with the other, communicates to it a lighter shade, must render it variable, and give rise to some difference of medicinal power. In conducting the process, therefore, every precaution ought to be taken to moderate the action of the acid on the metal. Five parts of diluted nitric acid, that is, the acid diluted with an equal weight of water, to four of quicksilver, are the proportions ordered in the Pharmacopœia; it may be diluted with one half more water; the quicksilver ought to be added in successive portions, and no heat is applied to accelerate the solution; the liquor is poured off from any undissolved mercury, and is diluted with fifteen parts of water; water of ammonia is then added as long as any precipitation is produced, and the precipitate, which is of a dark grey colour, nearly black, is collected on a filtre, washed with cold water, and dried. In drying, it becomes of rather a lighter shade. The nature of the action exerted by the ammonia in its production, is not altogether evident. The precipitate formed by it is different from that thrown down by potash or soda, hence its action must be peculiar. According to a view given by Fourcroy, the ammonia, in combining with the nitric acid of the solution, and separating the oxide of mercury, partially decomposes it, its hydrogen attracts part of its oxygen, and hence the oxide is thrown down in even a lower state of oxidation than that in which it existed in the solution. It has been supposed, too, that a portion of ammonia is combined with the oxide, but of this no trace can be discovered from the action of substances upon it, such as lime, by which ammonia, if present, would be expelled. The preparation is a mild mercurial, and is very similar in its operation on the system, to the mercurial preparations formed by trituration.

If any of the solutions of mercury in nitric acid be evaporated to dryness,—a mass is obtained of a yellowish colour, which, when urged with a strong heat gradually raised, becomes of a bright red, much of the acid being expelled or decomposed. This is a preparation which has been long known under the name of Red Precipitate of Mercury; it is now named Oxidum Hydrargyri Rubrum per Acidum Nitricum, in the Edinburgh Pharmacopœia; in the London, Hydrargyri Nitrico-Oxidum. When properly prepared, it is in scales of a brilliant red colour. It is not a pure oxide, but a sub-nitrate, and is accordingly different in its appearance and qualities from the red oxide obtained by the action of atmospheric air at a high temperature. It is probably impracticable to expel the whole of the nitric acid without decomposing the oxide itself; and that a portion of acid does remain in it, may be rendered apparent by a very simple experiment, boiling it in water, the liquor, when filtered, has a metallic taste, and gives a precipitate with water of ammonia, or carbonate of potash. It is employed as an escharotic, and this quality probably depends principally on the portion of acid it contains. Its proper appellation is Sub-nitras Hydrargyri Rubor. Decomposed by heat, 100 parts of it afford 82 of mercury, and 18 of oxygen gas, the latter having probably an intermixture of nitrogen gas.

Muriatic acid does not act on quicksilver, but it combines with it in the oxidated state, and exerts to its oxides a strong affinity. From the strength of this affinity it appears, even in entering into this combination, to render the degree of oxidation determinate, and accordingly two muriates of mercury, of uniform composition, are known, one or other of which is always formed when the acid is added to the metal in the oxidated state.

The formation of these compounds is well displayed in the action of muriatic acid on the solution of mercury in nitric acid. If the solution be in that state in which the metal is at the *minimum* of oxidation, a compound of the oxide with the muriatic acid is formed, which being insoluble, is precipitated. If the solution, on the contrary, contain the metal at the *maximum* of oxidation, a compound having very different properties is formed, and which, being easily soluble in water, remains dissolved. And if the mercurial solution be even in any intermediate state, the muriatic acid does not combine with the oxide in this state, but resolves it into the two oxides which are the bases of these compounds; and hence portions of both of them are produced, the relative quantities being various according as the solution has contained the metal more or less highly oxidated.

These two preparations have been long known, one by the name of Corrosive Sublimate of Mercury, the other by the name of Sweet Sublimate of Mercury, or Calomel; they are formed by processes very different from the modes of producing them which have just been described.

The process given in the Pharmacopœias to obtain the first of these preparations, consists in dissolving quicksilver in sulphuric acid, by the application of heat; a portion of the acid is decomposed, its oxygen is communicated to the metal, sulphurous acid being disengaged, and the oxide combines with the remaining acid. By continuing the application of heat, the sulphate of mercury is obtained dry; it is then mixed with twice its weight of dry muriate of soda, and the mixture being put into a glass matrass to which a capital is adapted, heat is applied to it by the medium of a sand-bath, and continued while any matter is sublimed. A double decomposition is produced; the sulphuric acid of the sulphate of mercury combines with the soda of the muriate of soda, while the muriatic acid unites with the oxide of mercury; and as this oxide existing in the sulphate, is in a high degree of oxidation, the muriate formed is the one with the oxide in this state. Being volatile, it is sublimed by the heat applied in its formation, and it condenses in the form of a crystalline cake in the upper part of the matrass. If it is sublimed more slowly, it is obtained in the form of needle-like crystals. It also crystallizes from its watery solution in prisms.

This salt is soluble in water, requiring about 20 parts at 60° for its solution, and not more than 2 parts at 212°. It is also soluble in alkohol. Its taste is styptic, it is extremely corrosive, and acts as a violent poison: in a very small dose it is, however, sometimes administered internally as a mercurial, and it is used externally as an escharotic. It is decomposed by the alkalis and earths, which precipitate from its solution a sub-muriate of a yellow colour. Ammonia forms a white precipitate, which is a ternary compound, consisting of 81 of oxide of mercury, 16 of muriatic acid, and 3 of ammonia. It has been in use as a mild escharotic, under the name of White Precipitate of Mercury. Muriate of ammonia has a singular effect on the muriate of mercury, that of rendering it much more soluble in water, and forming with it a compound which can be obtained crystallized. This compound, decomposed by potash, affords the same white precipitate. Sulphuretted hydrogen, either pure or combined with the alkalis, throws down from the solution of the muriate of mercury precipitates of a dark brown colour, which appear to consist chiefly of the sulphuretted oxide. A number of the metals decompose it by abstracting the oxygen of the oxide, either partially or entirely; and it even suffers a partial decomposition of this kind from vegetable extractive matter.

The composition of corrosive muriate of mercury has often been attempted to be determined. Even the latest analyses, however, assign different proportions of its constituent principles. According to Mr Chenevix, the oxide which is its base, is composed of 85 of mercury with 15 of oxygen, and 82 parts of this oxide are combined in 100 of the salt, with 18 of muriatic acid. In 100 parts, therefore, there are present 69.7 of mercury, with 12.3 of oxygen, with which 18 of acid are united. According to Zaboada, the oxide which is its base does not contain more than 10 of oxygen, and 80 of this oxide are combined with 20 of acid. The ultimate proportions, therefore, are 20 of acid, 71.5 of quicksilver, and 8.5 of oxygen.

The process by which the other muriate of mercury is formed, is an indirect one. It consists in triturating the corrosive muriate with nearly an equal weight of metallic mercury, facilitating the trituration by the addition of a little water, and continuing it until the globules are no longer apparent. The powder dried is put into a glass matrass, and sublimed by heat, applied by the medium of a sand-bath. As the new combination which takes place is not perfect on the first sublimation, the mass is reduced to powder, and sublimed a second, or even a third time. The sublimate is then obtained perfect, and free from metallic mercury; it is reduced to a fine powder by levigation, and is thoroughly washed and dried.

In this process the metallic mercury which is added is brought into combination with the principles of the corrosive muriate; it receives, therefore, a portion of the oxygen of the oxide which is the base of that compound, the whole passes to a lower state of oxidation, and the entire oxide thus formed remains combined with the acid of the corrosive muriate. Hence it is obvious, that the new compound differs from the other, first, in its base being mercury at a lower state of oxidation, and, secondly, in this base being combined with a smaller quantity of acid. Though the quantity of acid be smaller, it appears, however, to be as much as the oxide requires for its saturation, for it is incapable of neutralizing an additional portion of acid; and this is strictly conformable to a general law, exemplified in many metallic combinations, that a metal at a high degree of oxidation, requires a larger quantity of acid for its saturation, than when the oxidation is less perfect.

These two compounds, then, are muriates of mercury, and they afford an example of the difficulty of nomenclature, with regard to different salts formed from the same acid, united with the same metal in different states of oxidation; for it is not easy to assign to them distinctive appellations altogether unexceptionable. As the one contains a larger portion of oxygen than the other, it has been proposed to name it oxy-muriate, and the other muriate of mercury; but this is incorrect, the term oxy-muriate implying, in chemical nomenclature, a compound of oxy-muriatic acid, which this is not, the larger quantity of oxygen it contains being in combination with the metal, and not with the acid. In another mode of nomenclature, the one compound, that at the higher degree of oxidation, has been named Muriate; the other Sub-muriate of Mercury; but this is equally incorrect: the epithet *sub* is appropriated to salts in which there is a deficiency of acid, and this nomenclature would imply that the two compounds differed merely in the proportion of acid, their bases being the same. This is not, however, the difference between them. Although the compound named Sub-muriate has less acid in its composition than the other, this is because its base requires less for its saturation; it is not a subsalt, and its base is altogether different from that of the other. No better distinctive appellation can perhaps be given to them, than that drawn from any important property in which they differ; this, as has been already explained, affording on the whole the best mode of distinguishing salts formed from the same metal and the same acid. The one, therefore, may be named Corrosive Muriate of Mercury, the other Mild Muriate; and this also has the advantage of retaining the epithets by which they have long been distinguished, and of pointing out the difference between them, which it is most important to attend to in relation to their medical use.

Another mode of preparing mild muriate of mercury, besides that by sublimation, was introduced by Scheele. It consists in dissolving quicksilver in nitric acid, and adding to this a solution of muriate of soda; the muriatic acid combines with the mercurial oxide, while the nitric acid combines with the soda. The muriate is precipitated, it is thoroughly washed with water and dried. When this process is properly conducted, the product appears to be essentially the same with that formed by the other process. But from the theory of metallic solutions not being perfectly understood in the time of Scheele, he gave the improper direction of promoting the solution of the quicksilver in the acid by the application of heat. From this two effects arise, both giving rise to an alteration in the product; first, the decomposition of the acid being promoted, the metal passes to a higher state of oxidation than that in which it forms the base of the mild muriate, and hence a portion of corrosive muriate is also formed; and, secondly, the acid is so completely saturated with oxide, that water alone produces a partial decomposition of the solution, throwing down a sub-nitrate; and hence, on adding to it the solution of muriate of soda, a portion of this sub-nitrate is formed, and mingles with the precipitated muriate. These sources of alteration may be avoided by dissolving the quicksilver in the nitric acid, diluted with more than an equal weight of water, and avoiding the application of heat; a solution being thus obtained, which contains the metal in the lowest state of oxidation, and which affords the mild muriate alone, when decomposed by muriate of soda. But the process has no real advantage over that by sublimation, and as, from not being always properly conducted, it may afford a less uniform product, ought to be discarded.

Mild muriate of mercury, obtained by sublimation, is in the form of a dense mass of crystalline structure, composed of short prisms; and when sublimed slowly, it is obtained in tetraedral prisms, or in octohedrons. In its dense state, it has a specific gravity of 7.1; it is somewhat ductile, and is semitransparent, with a slight tinge of yellow. It is volatile, as is obvious from its mode of formation; it is so sparingly soluble in water, as to require above 1000 parts for its solution. It is insipid, has no escharotic power, and is mild in its operation on the system.

This compound is decomposed by the alkalis and earths, which partially abstract its acid, and form a sub-muriate of a grey colour.

Mr Chenevix observed the formation of an oxymuriate or hyper-oxymuriate of mercury, on transmitting a current of oxymuriatic acid gas through water in which red oxide of mercury was diffused. Along with crystals of corrosive muriate, another crystallized salt was obtained, more soluble in water, from which sulphuric acid expelled vapours of hyper-oxymuriatic acid.

Mercury is scarcely acted on by any of the other acids; its oxides, however, combine with the greater number of them, and form peculiar compounds. These combinations may be effected by digesting the oxide in the acid; but a more effectual mode is to add to the nitrous solution of mercury, either the acid designed to be combined with the oxide of mercury, or what is preferable, a solution of a neutral salt which contains this acid. Thus, if phosphoric acid be added to the nitrous solution of mercury, a phosphate of mercury is formed; or if, instead of the acid, a solution of phosphate of soda be added, the same compound is obtained,—the soda attracting the nitric acid, and the phosphoric acid combining with the oxide of mercury. In the same manner may be effected the combinations of the oxides of this metal with any other acid. None of these compounds are important, or applied to any use.

The oxides of mercury precipitated by the alkalis, especially by ammonia or lime, if dried with exposure to light, and triturated with 1–6th of their weight of sulphur, detonate on being heated. A more powerful fulminating preparation has been discovered by Mr Howard. It is obtained by dissolving 100 grains of mercury in one ounce and a half of nitric acid, with the assistance of heat; the solution, when cold, is *poured upon* two ounces of alkohol by measure; a moderate heat is applied, till an effervescence is excited, and a precipitate is formed; this, washed and dried, forms the fulminating mercury: 1½ or

2 grains of it, struck upon an anvil, explode violently; and the same effect is produced by a strong electrical discharge, by sudden friction, or exposure to heat. Mr Howard found this preparation to consist of oxide of mercury, oxalic acid, and nitrous etherised gas. Its detonation appears to be owing to the sudden combination of the oxygen with the carbon and hydrogen of these substances, forming aqueous vapour and carbonic acid, and disengaging nitrogen gas, while, at the same time, so much caloric is rendered sensible, that not only is the elasticity of these gases much increased, but even the metal, it has been proved by Mr Howard's experiments, is converted into vapour; and to the great elasticity of this mercurial vapour he ascribes its high explosive power.

Quicksilver combines with sulphur. By mere trituration the mercurial globules are extinguished, and a black powder is formed, the product of the combination of the two substances. It is the black sulphuret of mercury. When seven parts of the metal are triturated with one of sulphur, and the black powder they form is subjected to a moderate heat, the temperature rises, and light is evolved, apparently not from oxygenation, but from the combination of the sulphur and the metal. On subliming the residual mass, it acquires a very vivid red colour. This is the red sulphuret of mercury, the cinnabar or vermilion of commerce. Both the black and the red sulphurets have been supposed to contain oxygen, but this has not been established by any accurate analysis.

Mercury is acted on by the alkaline sulphurets when these are dissolved in water, a black powder being formed. These compounds, especially that from the sulphuret of ammonia, on exposure to the air, assume a red colour, and form a compound similar to cinnabar.

Mercury does not unite with carbon; it combines with phosphorus, forming a tenacious concrete mass, fusible, and which is decomposed by heat.

Quicksilver combines with many of the metals; it has not been practicable to unite it with iron, cobalt, antimony, or nickel, and it unites with platina with great difficulty. These compounds are brittle and soft, and when the mercury is in large proportion, are even fluid. They are named Amalgams. The amalgam of it with tin is used in silvering glasses; that with gold, or silver, in gilding or silvering the other metals: and from its property of amalgamating so easily with these two metals, quicksilver is employed in extracting them from the foreign substances with which they are naturally mixed.

CHAP. IX.

OF COPPER.

Copper is of a red colour, with a shade of yellow, having considerable lustre, but liable to tarnish and rust from exposure to the air. It is moderately hard, and has considerable ductility and malleability. Its specific gravity is 7.8. It has a sensible odour, especially when heated or rubbed, a styptic unpleasant taste, and is peculiarly noxious to health.

Copper occurs in nature native, and also mineralized by oxygen, by sulphur, united with other metals, and in the state of oxide combined with different acids. It is principally extracted from those ores in which it is associated with sulphur, these being most abundant. The ore is roasted by a low heat, the metal is reduced, melted, and, by repeated fusions, is obtained pure.

Copper melts at a full white heat, and by slow cooling may be crystallized. It suffers oxidation at a lower temperature from the action of the air, thin scales of oxide forming on its surface when it is heated to redness. At a higher heat it burns with a green flame. Its rusting from exposure to air and humidity at natural temperatures, probably likewise arises from oxidation, though some have regarded the green rust as a carbonate of copper. The degrees of oxidation of which this metal is susceptible, have not been determined with much precision. The brown oxide, formed in scales when it is ignited under exposure to the air, are supposed to be at the minimum of oxidation; and by exposing this to a red heat, or by oxidating the metal directly at a higher temperature, another oxide in a higher state of oxidation, containing about 25 of oxygen in 100 parts, is formed. Chenevix supposed that a still lower degree of oxidation than the former of these is established in some of the saline combinations of the metal, the proportion of oxygen being not more than 11.5 in 100 parts. The blue and green precipitates thrown down from the salts of copper by the alkalis and earths, are not pure oxides, as had been supposed, but sub-salts, containing, besides a small quantity of acid, a portion of combined water. None of the oxides of copper are entirely decomposed by heat.

Copper is oxidated and dissolved by the greater number of the acids, and forms with them in general soluble and crystallizable salts, of a green or blue colour.

Sulphuric acid, either concentrated or diluted, oxidates it, and combines with the oxide, especially when its action is promoted by heat. The solution is of a blue colour, and by evaporation affords crystals of the same colour in the form of rhomboidal prisms: they are soluble in four parts of water at 60, and in two parts at 212°, and are decomposed by heat, the acid being partially expelled. This salt is the blue vitriol of commerce, and is usually obtained either by evaporation of the solution of it formed by the infiltration of water through copper mines, or by exposure of sulphuret of copper to the action of air and humidity, until the sulphur is converted into sulphuric acid, and the metal is oxidated and combined with it.

Nitric acid acts on copper with much facility, the metal attracting a portion of its oxygen, nitric oxide gas being disengaged, and the oxide combining with the remaining acid. The solution is of a deep green or blue colour, probably according to the state of oxidation. When evaporated, it affords prismatic crystals of a deep green colour, deliquescent, and easily soluble in water. This salt, from the facility with which it parts with oxygen, acts with considerable energy on a number of substances. Thus it detonates when struck with phosphorus, and burns several of the metals. If wrapt, for example, in tinfoil, the tin in a few moments is oxidated, and frequently with such rapidity as to produce appearances of inflammation. To succeed in this experiment, it has often been remarked, that the salt must not be in a perfectly dry state, but that a little water must be added to it; this has been supposed to operate simply by communicating that fluidity necessary to chemical action, and the experiment has often been produced as affording a proof of this. I have found, however, that it depends on a different cause—the concentration of the acid; for if the solution be strongly evaporated, and the salt employed while it is still a little warm, though it be perfectly soft, and even humid, it does not act on the tin, until a little water is added. It is therefore an example of the singular fact, established by more direct experiments, that nitric acid highly concentrated does not act on metals, but requires the presence of a portion of water.

Muriatic acid dissolves copper slowly when the atmospheric air is admitted; if it is excluded, the action is very inconsiderable unless heat is applied; the solution is of a green colour, and by evaporation slender prismatic crystals are obtained, deliquescent and very soluble in water. The salt is decomposed by heat, and the acid disengaged partly in the state of oxy-muriatic acid. The combination of copper with muriatic acid can be established in other states of oxidation. Thus, if a portion of copper-filings be included in a phial closely stopt, with a solution of green muriate of copper, the solution gradually becomes colourless, the metallic copper attracting a portion of the oxygen of the dissolved copper; but that the solution still holds the metal dissolved at a lower degree of oxidation, is proved by the fact, that if the air be admitted, a blue tint is soon produced, and appears first at the surface of the liquid. By the addition too of muriate of tin, a substance which powerfully abstracts oxygen, to a solution of muriate of copper, a white muriate is precipitated, and this, by an addition of acid, forms a colourless solution. Oxy-muriatic acid dissolves copper, and when transmitted in its elastic form through water in which oxide of copper is suspended, the oxide disappears.

Copper is slowly oxidated by a number even of the weaker acids, as by sour vegetable juices, when submitted to their action in contact with the air and with humidity, while the acid alone does not appear to impart oxygen. The combinations of its oxide with phosphoric, carbonic, and other acids, are most easily effected by adding to a solution of nitrate or sulphate of copper, a solution of a neutral salt, containing the acid with which the copper is designed to be combined. The carbonate, phosphate, and borate of copper are thus obtained in the form of precipitates of a green colour, more or less deep. The fluate of copper can be obtained crystallized. Acetic acid or vinegar oxidates copper, forming on copper plates a crust of a green colour, the verdegris of commerce; and this, when dissolved in the acid, so that the oxide is neutralized, affords on evaporation prismatic crystals of acetate of copper, of a rich green colour.

All the saline combinations of copper are decomposed by the alkalis and earths. Potash, soda, and the alkaline earths, throw down precipitates which are of various shades of green or blue, according to the quantity of alkali added, the colour being green if a small quantity has been employed, and becoming blue from a larger quantity. These precipitates are sub-salts, the alkali attracting the greater part of the acid, but the oxide precipitated retaining a small portion of the acid combined with it. The green contains more acid than the blue. The blue was even supposed to contain no acid, and was regarded by Proust as what he named a hydrate of copper, or combination of oxide of copper and water: but the experiments of the younger Berthollet have sufficiently shewn, that it always retains a portion of the acid of the salt from which it is obtained. These precipitates retain a considerable quantity of water in combination, frequently as much as 12 or 15 in 100 parts in a dried state, and the oxides of copper carry with them usually a large proportion of water into their saline combinations.

The action of ammonia on the salts of copper is more peculiar. It first abstracts a portion of the acid, and throws down a precipitate of a green or blue colour, which is a sub-salt. But if added in larger quantity, it re-dissolves this precipitate, and forms a transparent solution of a very deep blue colour. It forms a similar solution with the pure oxides of copper, if the degree of oxidation be sufficiently high, for in a lower state of oxidation the solution is colourless, as is well shewn in the experiment of inclosing a few copper filings with the blue solution in a phial closely stopped; the colour is gradually removed by the metallic copper abstracting a part of the oxygen of the dissolved oxide; but that the oxide, in this lower degree of oxidation, is still in combination with the alkali, is shewn by the blue tint almost immediately appearing at the surface of the liquid when the atmospheric air is admitted. The ternary combinations of oxide of copper, acid, and ammonia, may be obtained in small crystals by evaporation of their solution, or by precipitation by alkohol. A similar compound, used in medicine under the name of Ammoniuret of Copper, is prepared by triturating two parts of sulphate of copper with one part of carbonate of ammonia, the mass becoming soft from the mutual action of the two salts, the carbonic acid being disengaged with effervescence, and the triple compound of sulphuric acid, oxide of copper, and ammonia, being ~~obtained of a deep~~ violet colour.

Copper is precipitated in its metallic state from its saline solutions by zinc and iron, these metals attracting the oxygen which serves as the medium of its union with the acid of the solution.

Copper and sulphur unite easily by fusion, the combination being attended with an elevation of temperature and an extrication of light. The compound is of a dark-grey colour, with a degree of metallic lustre, brittle and fusible. Sulphuret of potash combines with copper by fusion, and even by the intermedium of water. Sulphuretted hydrogen and the hydro-sulphurets throw down dark-coloured precipitates from its salts.

Copper appears to form a combination with carbon. This is not indeed obtained directly; but when the vapour of alkohol is transmitted through a red-hot copper tube, or over copper-filings placed in an ignited earthen tube, a substance is obtained, black and friable, which burns in oxygen gas, affording carbonic acid, and a residuum of oxide of copper.

Phosphorus may be combined with copper, by exposing to heat the metal in mixture with phosphoric acid and charcoal. The phosphuret is of a white or grey colour, with metallic lustre; it is hard and brittle, tarnishes on exposure to the air, and is decomposed by heat.

Copper combines with the greater number of the metals by fusion. It communicates hardness to gold and silver, without much diminishing their ductility, or debasing their colour, when in small proportion; hence it is employed in the standard alloys of these metals. With platina it forms an alloy ductile, and susceptible of a fine polish. Quicksilver easily amalgamates with it, and in small quantity renders it brittle. With zinc it forms brass and pinchbeck; with tin, bell-metal and bronze.

Copper, from its comparative fusibility, its ductility, the facility with which it can be extended in sheets, and with which it can be united by solder, is capable of being applied to many purposes of utility; and it is accordingly employed in the construction of boilers, stills, and various household utensils. Its utility is much limited by its poisonous quality; and though this has been attempted to be obviated, by coating its surface with a thin layer of zinc or tin, the precaution is scarcely effectual. In thin sheets, it is applied to sheath the bottoms of ships, and for this purpose is preferable to any other metal. Several of its combinations are used as pigments, and some are employed in the practice of medicine.

CHAP. X.

OF IRON.

THIS metal is extensively diffused. It exists in the mineral kingdom in immense quantity, and under numerous forms; there are even few fossils entirely free from it; it is a constituent principle of vegetable matter, and is obtained from the ashes of every plant; it exists in the composition of the blood, and of other animal products; and the singular fact has even been established, that it is an atmospheric or meteoric production, those stoney masses which at different times, and in different countries, have fallen from the atmosphere, containing iron as their principal ingredient.

The ores from which iron is extracted, are those in which it is mineralized by oxygen; of which there are many varieties, consisting of the oxide more or less pure, intermixed with argillaceous, calcareous, and siliceous earths. It is principally from the argillaceous ores that iron is extracted in this country. The ore is roasted to expel any foreign volatile matter; it is then put into a furnace with layers of coaked coal, and with a quantity of lime, and is exposed to an intense heat excited by a blast of compressed air. The lime combining with the other earthy substances in the ore, they vitrify more easily, so as to admit of the action of the carbonaceous matter of the coal on the oxide, and the separation of the metal reduced by the abstraction of the oxygen. The charge of fresh materials is renewed at the upper part of the furnace, and the process carried on without interruption, the vitrified matter being withdrawn by an opening in the side, and the melted metal run out at the bottom. It forms what is named crude iron, pig iron, or cast iron.

In this state it is not the pure metal; it always contains a portion of carbon and of oxygen; and frequently smaller portions of other ingredients, manganese, silex, argil, phosphorus, and chrome. The oxygen, carbon, and phosphorus, appear to be diffused through the metal in the state of oxide, carburet, and phosphuret of iron. According to the nature and proportions of the foreign substances, the qualities of the iron are modified. Three principal varieties have been distinguished;—white crude iron, in which the colour approaches to white, the fracture exhibits a striated appearance, and the mass is extremely brittle; the grey crude iron, in which the colour is grey and dull, the fracture granular, and which is less brittle than the other; and, lastly, the black crude iron, which is of a dark grey colour, approaching to blue, and the fracture of which presents larger granular concretions; it is also softer and more fusible than the others. The peculiar qualities of the first variety have been supposed to depend principally on the presence of oxygen, or perhaps rather oxide of iron; of the second, on the presence of this, with a portion of carbonaceous matter; and of the third, on the predominance of carbon, or rather perhaps carburet of iron. The production of them depends on the proportion of fuel to the ore in the process of reduction, and partly on the nature of the ore itself. The metal in all these states is much more fusible than when it is pure; hence it can be cast in a variety of forms; it is at the same time, however, more hard and brittle, and is therefore unfit for many of the purposes to which pure iron is applied.

To obtain pure iron, crude iron is submitted to two operations, fusion and forging. In melting it, part of the foreign matter separates and collects on the surface; and if kept in fusion for some time, the separation is rendered more perfect, a blue lambent flame appears on the surface, apparently from the disengagement of carbonic oxide, or carburetted hydrogen; and the metal, at first quite liquid, gradually becomes thick and viscid from its fusibility diminishing, and at length assumes the consistence of a paste; it is then submitted to the action of the forge-hammer, or to the pressure of steel rollers, by which a quantity of oxide of iron and other impurities is forced out. In this state it forms forged or bar iron, which is no longer granular, but fibrous in its texture; is soft, ductile, and malleable, and much less fusible; it is the metal in its pure form.

Still there are some peculiarities in forged iron, giving rise to different varieties. Apart from these peculiarities, iron is distinguished by its infusibility, softening when heated, and being ductile and malleable at all temperatures. One kind of forged iron has this ductility when cold, but is brittle at a high temperature; this is named hot short iron: another, named cold short iron, has precisely the opposite property, being ductile and malleable when heated, but brittle when cold. The causes of these peculiarities are not very well determined. The cold short property appeared, from Bergman's experiments, to depend on the presence of a substance which he regarded as a new metal, and named Siderite, but which has been ascertained to be phosphuret of iron. The hot short property has been ascribed to the presence of sulphur, arsenic, manganese, or chrome.

Forged iron, free from these peculiarities, is the metal in its pure state; it is ductile and malleable at every temperature; its texture is fibrous; its colour a light grey, accompanied in the fresh fracture with considerable lustre; its specific gravity is 7.7; in hardness it is superior to the greater number of the metals; it also exceeds them in ductility, being capable of being drawn into finer wire, and having such tenacity that a wire 0.078 of an inch in diameter supports without breaking above 500 pounds. It is also highly elastic.

Iron is peculiarly distinguished by the property of magnetism; it has even been supposed to be the only substance which possesses it; some other metals, however, particularly nickel and cobalt, appear also to be magnetic. The magnetic power remains within a certain degree of oxidation, but beyond this is impaired; it also remains when the iron is combined with a certain proportion of carbon, sulphur, or phosphorus, but beyond this it is weakened, and at length destroyed.

Iron is extremely infusible, and was supposed to be even incapable of being melted by any heat that can be excited in a furnace. Its fusion has been accomplished, however, at a temperature calculated to be between 155° and 160° of Wedgwood's scale. Crude iron melts at 130. At a temperature far below that which is necessary to its fusion, forged iron softens until its surface appears as if it were covered with a thick tenacious fluid; and this softening extends so far through the whole mass, that two pieces in this state hammered together unite firmly. This is the property of welding, so valuable with regard to iron, as rendering it capable of being worked; it is possessed besides only by platina, and by it in a very inferior degree. The temperature at which it takes place is about a white heat; if the temperature be raised much beyond it, the iron becomes brittle, and falls to pieces under the hammer.

Iron is oxidated by atmospheric air. Even at a common temperature, it undergoes the operation of rusting, in which it is oxidated. The change in this case, however, depends partly on the agency of water, as it is accelerated by humidity; and if the air is perfectly dry, it scarcely takes place. The rust, too, is not a pure oxide, but contains a portion of carbonic acid, absorbed from the atmosphere, or formed perhaps from the oxygenation of a little carbon contained in the iron.

At a high temperature, the oxidation of iron takes place more rapidly. When raised to a red heat, its surface assumes various tints of colour, and at length scales form upon it, consisting of the oxide. In the state of filings, it even burns brilliantly when projected across the flame of a burning body, and ignited iron-wire burns with splendour in oxygen gas. In these cases, what is named the black oxide of iron is formed, containing, according to Lavoisier's estimate, 27 of oxygen in 100 parts. If it be exposed to a continued heat, with the access of the air, it changes its colour and becomes red, from farther oxygenation. This red oxide contains 48 of oxygen in 100 parts. These oxides are obtained also by other processes. The black oxide is produced by the slow action of water on iron, when the iron is entirely immersed in it, and also in the more rapid decomposition of water, when it is transmitted over the metal at the temperature of ignition; it exists, too, in several of the saline combinations of iron. The red oxide is the base of those at a higher state of oxidation, and is obtained from their decomposition. And other oxides, in intermediate degrees of oxidation, probably exist. One of a white colour is obtained from muriate of iron, formed by boiling a large quantity of muriatic acid on iron-filings, and decomposed by an alkali, which has been supposed to be iron at a lower degree of oxidation than the black oxide. None of these oxides can be reduced by heat; but their reduction is accomplished by the action of carbonaceous matter at a temperature sufficiently elevated.

Iron, from the strength of its affinity to oxygen, is oxidated and dissolved by the acids with facility; its saline compounds, when neutral, are in general soluble and crystallizable.

Sulphate of iron is a salt which has long been known under the name of Green Vitriol. It is economically prepared from the native sulphuret of iron, which, when calcined, and exposed for some time to air and humidity, absorbs oxygen, so that the sulphur is converted into sulphuric acid, and the iron is oxidated; the sulphate of iron, thus formed, is extracted by lixiviation and crystallization. It is obtained more pure by the direct solution of iron in diluted sulphuric acid, the acid enabling the iron to decompose the water, by attracting its oxygen, and combining with the oxide, hydrogen gas being disengaged. The solution is of a pale green colour, and, if concentrated, affords, after filtration, crystals of the same colour, in the form of rhomboidal prisms. They consist of 28 of oxide of iron, 26 of sulphuric acid, and 46 of water. This salt is soluble in six parts of cold water. Exposed to heat, it first liquifies; when the water of crystallization is dissipated, it forms a dry mass of a greenish colour; when urged by a strong heat, the greater part of its acid is expelled, partially decomposed, and a red oxide remains. Exposed to the air, it loses its transparency, and is covered with a yellowish crust; a change owing not merely to the dissipation of the water of crystallization, but to the absorption of oxygen. This absorption takes place to a greater extent when the salt is in solution, and continues until the oxide pass to the maximum of oxidation. In this state it requires a larger quantity of acid for its saturation than the oxide in the green sulphate does; hence a portion of this more perfect oxide is precipitated, while the remaining quantity is retained in combination with the acid. The one of these salts is named the Green Sulphate of Iron, the other the Red Sulphate. The latter is not crystallizable, but when its solution is evaporated it forms merely a mass of a yellowish-red colour. It is soluble in alkohol, and this affords a mode of separating it from the other. With re-agents, these salts afford different phenomena. The green sulphate, decomposed by the alkalis, gives precipitates of a green colour; the red sulphate affords precipitates of a yellow colour, approaching more or less to red; the former, with prussiate of potash, gives a white precipitate, the other, with the same test, a precipitate of a rich blue colour; the one is little altered by the infusion of galls, the other strikes immediately a deep purple colour.

From the strong tendency of iron to pass to a highly oxidated state, it is difficult to obtain the green sulphate perfectly pure, so as to exhibit these phenomena. The solution of iron is usually in an intermediate state of oxidation; and though Proust and some other chemists have supposed that there are only two sulphates of iron of determinate composition, one having for its base the metal at the *minimum*, the other at the *maximum* of oxidation, and that any apparent intermediate compound is merely a mixture of these, it is more probable that there is a series of these compounds in indefinite degrees of oxidation; and accordingly crystals of numerous shades of colour can be obtained. The different precipitates which the compounds at the extremes of the series form with the different re-agents, the prussiate of potash, and infusion of galls, have been supposed to depend on the peculiar properties of the oxides which are their bases*: this may be partly the cause, but they appear also to arise in part from the different forces of affinity with which the oxide is retained in combination with the sulphuric acid, the force being greater as exerted towards the metal at a low than at a high degree of oxidation, so that the salt in the former state does not so easily form a precipitate with these reagents. But if the affinity be weakened by causes which do not change the state of oxidation, as by mere dilution with water, or the addition of an alkali in small proportion, the precipitation is produced by their action on the salt in even the least oxidated state.

Sulphate of iron is a salt applied to numerous uses in the arts, more particularly in dyeing, as forming, with vegetable astringents, the bases of black dyes, and, with other colouring substances, different shades of colour. Its combination with these astringents is also the basis of writing-ink.

Sulphurous acid dissolves iron, being partly decomposed, so that the combination is a sulphuretted sulphite of iron. The pure sulphite is obtained by the direct combination of the acid with oxide of iron; it is soluble in water, not soluble in alkohol, and is not coloured by infusion of galls.

Nitric acid is decomposed by iron with great rapidity, and the metal passes to the highest state of oxidation. When the acid is diluted, the action is more moderate, and a more perfect solution is obtained, which, however, cannot be evaporated so as to afford the nitrate crystallized, the heat that is required causing a farther decomposition of the acid, and the precipitation of a sub-nitrate of iron.

A similar change is produced in the solution from exposure to the air, oxygen being absorbed.

Muriatic acid dissolves iron with facility, the iron receiving oxygen from the water, and the solution being therefore attended with a disengagement of hydrogen gas. The solution is of a pale green colour, and affords crystals on evaporation of the same colour. If oxide or rust of iron is dissolved in muriatic acid, a solution is obtained of a yellow colour, more or less deep, which does not crystallize on evaporation, but affords merely a soft deliquescent mass. In the one of these salts, the iron is in a low, in the other in a high state of oxidation, and they differ considerably in their chemical properties; the former, the green muriate, is insoluble in alkohol, is little altered in its colour by infusion of galls, and, when decomposed by the alkalis, gives a green precipitate; the latter, the red muriate, is soluble in alkohol, gives a deep purple colour with galls, and a blue with prussiate of potash, and affords a yellow precipitate when decomposed by the alkalis. The green is converted into the red muriate by exposure to the air, passing through various intermediate states of oxidation, by absorption of oxygen.

The solution of the green muriate, as well as of the green sulphate of iron, absorbs nitric oxide gas; a property, the application of which to eudiometry has been already stated.

Iron is acted on by water strongly impregnated with carbonic acid, and a portion of it is dissolved. The common rust of iron contains a portion of this acid; and a carbonate is formed by decomposing sulphate of iron by carbonate of potash or soda; it is precipitated of a greenish colour, but in drying becomes brown from absorption of oxygen from the air. In the natural chalybeate waters, the iron is usually held dissolved by carbonic acid.

Phosphoric acid acts weakly on iron; but the phosphate may be formed by adding phosphate of soda to a solution of sulphate of iron; it is of a white colour, insoluble in water, and fuses into a brilliant globule by an intense heat. The borate, formed by a similar process, is likewise insoluble. The fluate is soluble, does not crystallize, but by evaporation forms a gelatinous mass. Prussic acid has a powerful affinity to oxide of iron; it forms with it the pigment of a rich blue colour, known by the name of Prussian Blue; and from the deepness of the colour of this combination, and the strength of affinity which the acid exerts, it affords one of the most delicate tests of iron. Gallic acid produces with the salts of iron a deep violet tinge, and in the state in which it is combined with tannin in the infusions of vegetable astringents, particularly of galls, is a test still more delicate and more accurate.

The alkalis scarcely act on iron or its oxides; in decomposing its salts, they in some cases form, when added in excess, soluble ternary compounds. The earths form coloured enamels, when melted with oxide of iron.

Iron appears to exert a strong attraction to carbon. When melted from its ores in contact with the fuel, a portion of carbonaceous matter combines with it, and this, with oxygen and other ingredients, forms cast iron. The combination of iron with carbon alone constitutes Steel, one of the most useful forms of this valuable metal.

The usual process for forming steel is that of Cementation, bars of malleable iron being imbedded in layers in charcoal powder in a close furnace, through which flues are carried to distribute the heat. A strong fire is applied for six or eight days; the progress of the cementation is known by withdrawing a bar from the furnace; if this is sufficiently changed, the fire is extinguished, and the metal is left to cool for six or eight days. This forms Blistered Steel; it is rendered more perfect by subjecting it to the operation of the forge-hammer, as in forging iron; or by welding it; or it is fused and cast into small bars, forming what is named Cast Steel. These operations are performed on malleable iron; but some kinds of cast iron, particularly of the grey crude iron, can be converted into steel of an inferior quality by a similar process. Steel is also formed by fusing forged iron with charcoal.

In this operation, an increase of weight from $\frac{1}{180}$th to $\frac{1}{140}$th is gained. The more carbon is introduced, the more brittle is the steel. Bergman first clearly shewed the presence of this carbonaceous matter, by ascertaining by experiment, that less hydrogen is disengaged during the solution of steel in diluted sulphuric acid, than during the solution of iron in the same acid; and that, during the solution of the steel, carbon is precipitated in the form of a black shining powder, similar to plumbago. Guyton has observed, that it is probably pure carbon, not charcoal, that is present in steel; and to this its great hardness may be ascribed. This has been confirmed by the interesting experiment of converting iron into steel, by exposing it to heat with diamond. If the ultimate base of carbon be metallic, as is not improbable, it may be this metallic matter that combines with iron to form steel. Bergman further found, that some specimens of steel contain manganese and siliceous earth; and Vauquelin has likewise discovered the existence of this earth and of phosphorus in several kinds of steel which he analyzed.

Steel is of a grey colour; its fracture is granular and brilliant, and it is susceptible of a very high polish. It is more fusible than iron. It is both ductile and malleable, and when hammered, its ductility and also its elasticity are increased. The property by which it is eminently distinguished is, that of acquiring a great degree of hardness by being immersed in cold water when previously heated, the hardness being greater as the steel has been hotter and the water colder; it at the same time becomes more brittle and elastic, effects which evidently arise from the irregular aggregation produced by the sudden cooling. Steel, thus hardened, may have its softness and ductility restored, by again heating it, and allowing it to cool slowly. This is what is termed *tempering* of it, the requisite degree of hardness being given by heating the metal more or less, previous to the slow cooling. The harder it is, it is also the more elastic, and at the same time more brittle, and hence, for different purposes, different degrees of *temper* are required.

Steel possesses a degree of hardness superior to any other metal; it is also possessed of the highest elasticity: and from these properties it acquires its high value.

The mineral substance known by the name of Plumbago, or Graphite, is a native combination of iron and carbon. The proportion of iron is variable, but in general it does not exceed from 5 to 10 in 100 parts; it is in combination, as Mr Davy has supposed, with the pure carbonaceous base.

Iron has a strong attraction to sulphur, and combines with it with facility by fusion, the combination being attended with the evolution of heat and light. They also exist combined in nature, the mineral named Pyrites being a combination of this kind. The proportions of the ingredients in the native sulphurets, are usually different from those in the artificial sulphuret; in the former they are about 53 of sulphur, and 47 of iron; in the latter the proportion of sulphur does not exceed 37; but the artificial sulphuret may be combined by fusion with an additional proportion of sulphur, and sulphurets formed in various intermediate proportions. When the proportion does not exceed 37 of sulphur in 100 parts of the compound, the magnetic property remains; but when it is so high as 53, it is entirely destroyed. These compounds are of a grey or yellow colour frequently variegated, with a degree of lustre, the colour approaching more to yellow, and the lustre being more perfect, as the proportion of sulphur is large. They are of a crystalline texture, brittle, fusible, and are partially decomposed by heat; the compound in which the iron predominates, when moistened and exposed to the air, absorbs oxygen, and is gradually converted into sulphate of iron. A mere mixture of iron filings and sulphur moistened acts on atmospheric air in a similar manner, and suffers the same change. The alkaline sulphurets combine with iron by fusion, and also by boiling with water. Sulphuretted hydrogen, and the hydro-sulphurets, form precipitates from the salts of iron.

With phosphorus iron forms a compound, white, brittle, and of a granular fracture.—A compound of this kind, obtained from cast iron, was once regarded as a peculiar metal, and named Siderite. It has been considered as the cause of the cold short property of iron.

Iron combines with a number of the metals, but few of its alloys are applied to use. That with gold is, hard, ductile, and malleable, but of a dull grey colour. With silver it forms an imperfect combination. With platina the combination is not easily effected, from the infusibility of both metals. It does not easily amalgamate with quicksilver; the combination can only be produced by indirect methods, and is imperfect. The alloy with copper is brittle, and of a grey colour. The principal alloy of any use is that with tin, this forming what is named Tinned Iron.

Iron is perhaps the most useful of the metals, possessing in its pure form the highest degree of tenacity, ductility, elasticity, and hardness, combined, whence it is applied to all purposes where strength is required; and though infusible, it is capable, by the singular operation of welding, of being easily fashioned and worked. Cast iron, being fusible, can be adapted to other purposes, and derives value from its hardness, and from being less liable than forged iron to be acted on by the air. And the great elasticity and hardness of steel adapt it to numerous uses, for which other metals would afford very imperfect substitutes.

CHAP. XI.

OF LEAD.

Lead is the softest and least elastic of the metals; it has little ductility, but considerable malleability; its lustre tarnishes speedily; its specific gravity is 11.3; when rubbed it has a peculiar smell; it has also a perceptible taste, and is one of those metals which prove most noxious to animal life. Its action too, as a poison, is very insidious, being liable to accumulate in the system, without immediately producing any sensible effect.

Lead occurs mineralized by carbonic, sulphuric, phosphoric, and molybdic acids, and by sulphur. It is from the last of these ores, the Galena of mineralogists, that the greater part of the lead of commerce is extracted; the ore reduced to powder being mixed with lime, and exposed to a sufficient heat; the lime combines with the sulphur, and the lead is run out. The other ores are previously roasted, and are treated in a similar manner.

Lead melts at a temperature a little inferior to ignition, or about 594° of Fahrenheit. When cooled slowly, it crystallizes in aggregated pyramids. By an intense heat it is volatilized.

When in fusion it is oxidated with great facility by the atmospheric air; its surface is quickly covered with a film which increases, and a grey powder accumulates, consisting of the metal in the first stage of oxidation. This, by exposure to a higher heat, acquires a lively yellow colour, forming what is named Massicot, a change probably owing to farther oxygenation. If the flame be made to reverberate on its surface, and it be constantly stirred, the colour changes to a bright red, and the substance named Minium, or Red Lead, is formed. By applying heat quickly to the oxide, directing at the same time a current of air over its surface, it is semi-vitrified, and forms a substance in thin scales, named Litharge. This, by a more powerful heat, may be completely vitrified, when it forms what is named the glass of lead. It is probable that the degrees of oxidation of lead are nearly indefinite, there being no external circumstance connected with their formation to render them determinate. The proportion of oxygen in the grey oxide has not been determined. In the yellow oxide obtained by decomposing the nitrate of lead, the proportion of oxygen, according to Proust, amounts to 9 in 100 parts, according to Dr Thomson 10.3. In minium, the quantity of oxygen is equal to 12 parts. Litharge, Dr Thomson found to contain about 4 parts of carbonic acid in 100, united with the yellow oxide. The existence of a brown oxide, formed by the action of nitric acid, or oxy-muriatic acid on the red oxide, has also been supposed containing a larger proportion of oxygen than any of the others. All the oxides of lead have a considerable specific gravity; they are fusible, and act as powerful fluxes on earthy matter. The red oxide is partially decomposed by heat, giving out a portion of oxygen gas. It and the other oxides are easily reduced by heating them with carbonaceous matter.

Lead does not decompose water, so as to produce any sensible disengagement of hydrogen gas; but when kept immersed in water for some time, it is encrusted with a white substance, formed probably from the action of the oxygen which water holds loosely dissolved.

Lead is oxidated by a number of the acids, and its oxides combine with them easily. Its salts, those of them at least which are soluble, are distinguished by a peculiar sweet and styptic taste.

Sulphuric acid has little sensible effect on it, unless its action is aided by a high temperature, and even then the action is imperfect. The neutral sulphate of lead, formed by decomposing any of the soluble salts of lead by an alkaline sulphate, is very sparingly soluble, so as to be instantly precipitated. With an excess of acid it becomes more soluble, and by evaporation of its solution, is obtained in needle-like crystals.

Nitric acid acts more readily on lead, oxidating and dissolving it; the solution by evaporation affords small pyramidal crystals, white and semi-transparent, with adamantine lustre. They are decomposed by heat, and deflagrate when thrown on burning fuel. Muriatic acid exerts but a feeble action on metallic lead; it combines, however, with its oxides, forming a compound not easily obtained without an excess of acid. The neutral muriate is best formed by decomposing any of the soluble salts of lead by muriate of soda; being very sparingly soluble in water, it is immediately precipitated: it can be so far dissolved, however, by the aid of heat, as to afford, by evaporation of its solution, slender prismatic crystals. It melts at a moderate heat, and forms, on congealing, a solid semi-transparent mass, which, from its appearance, has been named Horn Lead. By urging it with a stronger heat, it is partially decomposed. Oxy-muriatic acid, by its action on metallic lead, forms nearly the same compound. When transmitted through water in which the red oxide is diffused, it brings it to a higher state of oxidation, and combines with this oxide, forming a salt more soluble than the muriate.

Phosphoric acid has scarcely any sensible action on lead, but combines with its oxide, forming, when the combination is established by the exertion of a double attraction, a compound of very sparing solubility. Nearly the same relations are displayed by fluoric and boracic acids. Carbonate of lead, when it is formed by a similar process, is likewise insoluble. Cerusse, or white lead, is a sub-carbonate. It is prepared by exposing plates of lead to the vapour of vinegar; a white crust forms on their surface from the oxidation of the metal, and the oxide either absorbs carbonic acid from the atmosphere, or the portion of this acid combined with it, is formed from the partial decomposition of the vinegar. When cerusse is boiled with vinegar, it is dissolved, and by evaporation, a salt is obtained in slender prisms aggregated, the sugar of lead of commerce, the super-acetate of lead.

The salts of lead are decomposed by the alkalis and earths. If an excess of the decomposing substance is added, part of the precipitate is redissolved, and the fixed alkalis and lime, when boiled in solution on the oxides of lead, dissolve a minute portion of them. The earths vitrify with them with great facility, and oxide of lead is powerful in promoting the vitrifaction of all earthy mixtures.

Oxide of lead can, on the other hand, decompose a number of the alkaline and earthy salts, particularly the muriates and sulphates. When triturated with muriate of ammonia and a little water, the mixture soon disengages an ammoniacal odour from the oxide combining with the [illegible]. When triturated in a similar manner with muriate of soda, on continuing the trituration, and allowing the mixture to stand in a humid state, the decomposition of the salt is complete, the soda being dissolved by the water, while the oxide and acid remain in combination. These decompositions appear to be owing to the affinity of the oxide of lead to the acid being aided by its quantity; and accordingly a large quantity of oxide, four parts to one of the salt, are necessary to the decomposition; and the residual matter is sub-muriate of lead with a great excess of oxide. The process has been carried on on a large scale to obtain soda from muriate of soda, the sub-muriate of lead forming, when exposed to heat, a substance of a yellow colour, the sale of which as a pigment rendered it more economical.

Lead does not unite with carbon. With sulphur it combines by fusion, forming a compound of a dark-grey colour and metallic lustre. Sulphuretted hydrogen tarnishes the lustre of lead, and it decomposes its saline compounds, forming a precipitate of a very dark colour, which appears to be a sulphuret of lead, the hydrogen of the sulphuretted hydrogen combining with the oxygen of the oxide, while the sulphur unites with the lead. The action of the sulphuretted hydrogen combined with the alkalis or earths, is similar. It affords the most delicate test to discover the presence of lead, and is sometimes employed to detect it where it is suspected to be present in wines or other liquors, the solution of the sulphuretted hydrogen, or what is more frequently employed, of the sulphuretted hydro-sulphuret of potash, being added to the liquor. It is liable to some fallacies, however, from precipitating other metals, as iron, likewise of a dark colour; and this is only imperfectly obviated by different additions which have been made to what are named the wine tests; to render it certain, therefore, the precipitate ought always to be reduced to the metallic state. From the deepness of the colour produced by the action of sulphuretted hydrogen on the salts of lead, solutions of these form a well-known sympathetic ink, lines traced with any of them on paper becoming visible when exposed to the gas.

Lead forms with phosphorus a compound of a greyish-white colour, and metallic lustre, soft so as to be easily cut by a knife, flexible, and of a lamellated texture.

With the greater number of the metals lead combines easily by fusion, but few of its alloys are applied to any useful purpose. It diminishes greatly the ductility of gold, silver, and platina. It amalgamates readily with quicksilver, forming alloys more or less solid, according to the proportions. With copper it forms an alloy of a grey colour; with iron it can scarcely be combined.

Lead is adapted to many purposes of utility, from its flexibility, the facility with which it is cast into different forms, and with which, when in sheets, it is united by solder. In thin sheets, it is employed for covering the roofs of buildings. It forms evaporating vessels and boilers, to which the fire may be directly applied. And pipes formed of it are in common use for conveying water; an application which has not been supposed to be altogether without danger, as lead suffers a slight oxidation at its surface when immersed in water; in water conveyed through leaden pipes, however, no indication of the presence of lead can be discovered by the action of sulphuretted hydrogen; and from the perfect exclusion of the atmospheric air, the metal is probably little acted on by the water. The use of cisterns of lead for containing water must be more hazardous, as in these the metal is exposed to the action both of air and water; and they are probably rendered safe only from the deposite of the earthy matter contained in spring water, which forms a crust covering the surface of the metal. The oxides of lead are employed as pigments, and in the manufacture of the finer kinds of glass, to which they communicate greater density, and a higher refractive power. They are also used in glazing the coarser kinds of earthen ware, another practice which is not without hazard, as the glazing is easily acted on by liquors slightly acid. Several preparations of lead are employed in medicine, from their styptic power.

CHAP. XII.

OF TIN.

Tin has a white colour, with a slight shade of grey; it has little ductility, but so much malleability as to be capable of extension into thin leaves; it is soft and flexible, and in bending gives a peculiar crackling noise. It is one of the lightest of the metals, its specific gravity being not more than 7.3. It occurs in nature in the state of oxide, and in smaller quantity in that of sulphuret, and is one of the metals of least extensive distribution, being found in comparatively few countries. It is extracted from the native oxide by fusion in contact with the fuel, the oxygen being abstracted by the carbonaceous matter.

Tin is one of the most fusible of the metals, its melting point being not higher than 442°. When in fusion, if it is exposed to the atmospheric air, a film quickly forms on its surface, and a grey oxide accumulates. If this be longer exposed to heat, and stirred, it becomes of a yellowish-white colour, from passing to a higher state of oxidation. When tin is exposed to a high heat, it burns with a weak flame; and it is also oxidated with the phenomena of combustion, when exposed to a full red heat in mixture with nitre. The grey oxide has been supposed to contain from 8 to 10 of oxygen in 100 parts; the oxide at the *maximum* formed by the action of nitric acid on tin, contains, according to Proust, 30 or even 40 in 100 parts. These oxides are reduced with facility by exposure to a sufficient degree of heat in mixture with carbonaceous matter. They are extremely infusible, but vitrify with earthy substances.

Tin loses its lustre from exposure to the air, but is not liable to rust. It suffers little change from the action of water at any temperature.

Tin is oxidated and dissolved by the acids, and in these combinations is displayed one of the most characteristic properties of this metal, the avidity with which it combines with oxygen, and its tendency to pass to a highly oxidated state, so that the compounds at the *minimum* of oxidation are not easily obtained.

When heat is applied to favour its action on sulphuric acid, the acid is decomposed, and the decomposition proceeds to that extent, that not only is sulphurous acid disengaged from the partial abstraction of oxygen, but from its entire abstraction sulphur is separated. The solution deposites slender crystals; it is decomposed by the affusion of water, and suffers even spontaneous decomposition when kept for some time, the oxide passing gradually to so highly an oxidated state, that it exerts a less energetic action on the acid. Sulphurous acid is also decomposed by tin; a portion of sulphuret of tin appears to be formed, and sulphite of tin is partly precipitated, partly retained in solution.

Nitric acid, in its most concentrated state, exhibits the same singular phenomenon with tin that it does with some other metals; it is not decomposed by the metal, nor does it produce on it any change. But if somewhat weaker, or if a little water is added, the mutual action is rapid and violent, dense vapours of nitrous acid are disengaged, and the tin is so highly oxidated, that it is not dissolved, and appears scarcely to be combined with any of the acid. If the acid is more largely diluted, a more perfect solution is obtained, though still attended with the abundant disengagement of nitric and nitrous oxides. Such is the avidity even of this metal to oxygen, that the decomposition of part of the acid is complete; the water is at the same time decomposed by the abstraction of its oxygen, and the nitrogen of the one and hydrogen of the other being evolved, are presented to each other in their nascent state, unite and form ammonia, with which a portion of the acid combines. In the solution formed with the concentrated acid, the metal is oxidated to the *maximum;* when a dilute acid has been employed, it is less highly oxidated; it is not, however, permanent, but continues to attract oxygen from the acid, so as to become at length insoluble.

Muriatic acid dissolves tin slowly in the cold, and more rapidly when heat is applied, hydrogen gas being disengaged: this gas, it has often been remarked, has a peculiar fœtid odour, somewhat approaching to the arsenical odour, and it has hence been supposed to hold arsenic dissolved derived from the tin; it is more probably owing to the solution of a portion of tin itself. The solution of muriate of tin deposites, when concentrated, needle-like crystals, which are somewhat deliquescent; they are not dissolved in water without being partially decomposed, and sub-muriate of tin precipitated. In this combination, the tin is at a low degree of oxidation, but it has a great tendency to pass to a more highly oxidated state, and in consequence of this, this solution acts with energy on a number of the compounds of oxygen, particularly the metallic salts, decomposing them partially, or even in some cases completely, by attracting oxygen. It attracts oxygen, too, from several of the acids, and absorbs it from the air.

The muriate of tin, at the *maximum* of oxidation, is possessed, when in its concentrated state, of some very peculiar properties. The process long known to chemists, by which it is obtained in this state, consists in exposing to heat a mixture of an amalgam of tin and quicksilver with corrosive muriate of mercury; the oxygen and muriatic acid being transferred from the quicksilver to the tin, and the muriate of tin obtained by distillation. It forms a dense liquid, which exhales vapours when exposed to the atmosphere; these consisting of the muriate, which, in this concentrated state, is highly volatile, combining with the watery vapour of atmospheric air; their odour is acrid; the liquid, on being presented to water, combines with it with a hissing noise, and the disengagement of an elastic fluid. When combined with about one-third its weight of water, it forms a solid mass, which melts on the application of heat, and congeals by cold.

Nitro-muriatic acid dissolves tin with great rapidity; to obtain a proper solution, it is even necessary that the action should be moderated by dilution with water, and by adding the metal in successive portions; otherwise it is so highly oxidated, as scarcely to enter into combination with the acid. The solution, when concentrated, soon acquires a gelatinous consistence, and at length becomes firm. It is also at once rendered gelatinous by the affusion of water, which decomposes it, and precipitates the oxide, this remaining diffused through the liquor, and rendering it white and opaque. This solution is an important mordant in the art of dyeing, rendering several colours, particularly scarlet, more brilliant and permanent.

The phosphoric, fluoric, and boracic acids, form with the oxides of tin insoluble compounds.

The alkalis unite with oxidated tin; when employed to decompose the salts of tin, they re-dissolve the precipitate when added in excess; and after some time a partial decomposition is produced in the solution, one portion of the oxide of tin passing to a more highly oxidated state, while the portion losing this oxygen is reduced, and appears in the form of metallic arborescence. The ternary compounds of oxide of tin, with portions of acid and of alkali, are even capable of crystallizing. The alkalis dissolve likewise the oxide, independent of the presence of any acid,—exerting, in conformity to the law already stated, the strongest attraction to the metal in its more highly oxidated state. Some of these combinations likewise crystallize.

Tin and its oxides decompose several of the neutral salts, especially those having ammonia for their base.

Tin and sulphur unite easily by fusion; the compound is of a grey colour with metallic lustre, and may be obtained crystallized in cubes; with oxide of tin sulphur unites, forming a compound of a golden colour and lustre, and flaky appearance, named *aurum musivum*, and sometimes used for ornamental purposes. It may be formed by various processes, but the one usually followed is to melt twelve parts of tin in a crucible; and as it cools, add three parts of quicksilver, completing the amalgamation by trituration. It is then intimately mixed with seven parts of sulphur and three parts of muriate of ammonia: the mixture is exposed to heat in a matrass as long as any white vapours are disengaged: the heat is then moderately increased, a little sulphuret of mercury and muriate of tin sublime, and the *aurum musivum* remains at the bottom of the matrass.

The theory of the formation of this compound is intricate, but it appears to have been sufficiently ascertained by the researches of Pelletier. In the first amalgamation and trituration of the mercury and tin, the latter is divided, and in some degree oxidated; when the mixture of this amalgam with the sulphur and muriate of ammonia is heated, the muriatic acid, by a resulting affinity, enables the tin to be oxidated by decomposing the water, and this oxide combines with the muriatic acid; the hydrogen of the water is disengaged, with the ammonia of the muriate of ammonia, this ammonia uniting with a portion of the sulphur, and forming sulphuret of ammonia, which being disengaged, causes the white fumes. The heat being now augmented, the muriate of tin is again decomposed, the oxide of the metal attracts a portion of sulphur, and forms the *aurum musivum*. In conformity to this theory, Pelletier found that, by combining oxide of tin and sulphur by several more simple processes, the same compound is formed.

Sulphuret of potash combines with tin by fusion; the compound is partly soluble in water: if an acid is added to the solution, the tin is precipitated in combination with sulphuretted hydrogen. The metal is tarnished by sulphuretted hydrogen gas, and the alkaline hydro-sulphurets form coloured precipitates with its saline compounds.

Tin combines with phosphorus; the compound has the metallic brilliancy, is of a white colour and foliated texture, and so soft that it can be cut with a knife.

With the greater number of the metals tin combines with facility, and several of its alloys are in common use. It had always been believed, that in combining with gold it destroys its ductility, though present even in the most minute quantity. From the experiments of Alchorne, this appears however to be a mistake, and it had probably originated from the operation of some of the other metals, which the tin of commerce contains in small quantity. It has also been supposed to destroy the ductility of silver, an opinion probably resting on the same foundation. It combines with platina, and amalgamates easily with quicksilver; when the proportion of quicksilver is only one fifth, the alloy is solid and capable of crystallizing. With copper a series of valuable alloys are formed, bronze, bell-metal, and others. Bronze is the one in which the proportion of tin is smallest; it does not exceed 10 or 12 parts in 100; it is harder than copper, less liable to rust, and when melted, runs thinner, and therefore takes a more delicate impression from a mold; hence its adaptation to the fabrication of statues and ornamental vessels. The metal of which pieces of artillery are cast is of similar composition. An alloy nearly of the same composition was in use among the ancients, for the fabrication of swords, darts, and other warlike instruments, Dr Pearson having analyzed different ancient instruments of this kind, and found the composition to be eight or nine parts of copper with one of tin, and from its hardness it affords, as he remarks, the best substitute for iron or steel. Of the same alloy ancient medals and coins appear to have been often formed. When the proportion of tin is larger, the alloy becomes more brittle; it is also highly sonorous; it then forms bell-metal. With the tin considerably increased in quantity an alloy is formed nearly white, of a close texture, susceptible of a fine polish, and not liable to tarnish, and, from these qualities, well adapted to the purpose to which it has been applied, that of forming the speculum of reflecting telescopes; the addition of a small portion of arsenic and zinc adds to the density and whiteness. The composition recommended from the latest experiments, those by Mr Little, is 32 of copper, 4 of brass, 16½ of tin, and 1¼ of arsenic. Lastly, from the affinity between tin and copper, the latter metal can be covered with a thin layer of the former; this tinning of copper is executed by applying melted tin to the surface of the copper, perfectly clean and preserved from oxidation at the temperature to which it is raised by the application of muriate of ammonia, or sometimes of pitch; by this covering the noxious impregnation which might be communicated from copper-vessels to liquors boiled or preserved in them, is supposed to be prevented, though, as the coating is thin and easily eroded, it may be doubted if it affords any security.

Tin and iron unite by fusion, forming alloys with properties in some measure intermediate according to the proportions. Plates of iron immersed in melted tin unite with it at both surfaces, forming tinned iron, which, in the fabrication of small vessels, has the advantages over iron of being more flexible, less liable to rust, and easily united by solder. Tin and lead, differing little in their fusibilities, can be united in all proportions, and the compounds are nearly intermediate in physical properties, but more fusible. Pewter is an alloy of this kind, with the addition sometimes of a little copper and zinc. Equal parts of tin and lead form soft solder.

The amalgam of tin is used as a covering to glass mirrors, to enable them to reflect the light, and glass globes are sometimes coated internally by a similar amalgam.

It is in the formation of these alloys that tin is principally employed. Its oxides are used in enamelling, and to polish the metals; and its solution in nitro-muriatic acid is a valuable mordant in the processes of dyeing.

CHAP. XIII.

OF ZINC.

Zinc is a metal which appears to have been discovered during the researches of alchemy. It exists in nature mineralized by oxygen, with or without carbonic acid, and by sulphur. From the first of these ores, the calamine of mineralogists, it is extracted by a process founded on its volatility. The calamine, calcined with a low heat, is mixed with charcoal powder; the mixture is put into conical pots closed at the head, a tube which rises nearly to the top within descending through the bottom, and terminating in a vessel of water beneath. A sufficient degree of heat is applied around the pot, the oxide of zinc is reduced, and the metal volatilized is condensed at the termination of the tube.

Zinc is of a bluish-white colour, accompanied in the fresh fracture with considerable lustre, but liable to tarnish from exposure to the air; its texture is striated, it is hard, and has a specific gravity of 7.2. It was usually placed among the semi-metals, as having little ductility or malleability; it was always known, however, to have these properties to a certain extent; and more lately it has been shewn by Mr Silvester, that at a certain temperature, it can both be drawn into wire, and extended in thin plates, so as to be applied to purposes of utility founded on these properties. The temperature at which this can be effected is between 210 and 300 of Fahrenheit; and by annealing, it retains its tenacity when cold, so as to admit of being easily bent. At a higher temperature it is brittle.

Zinc melts nearly at ignition, and, when heated to a higher point, is volatilized unchanged. If the air is admitted to it when in fusion, its surface is covered with a grey oxide, and, if heated fully to ignition, the oxidation becomes more rapid, and is attended with a vivid light, and considerable heat; an oxide is formed in light white flocculi, which are in part carried off by the rapid current of heated air arising from the surface of the burning metal. The oxide itself is not volatile, but vitrifies when urged by an intense heat, forming a transparent glass of a yellow colour. The oxide formed by the rapid oxidation consists of 80 of zinc and 20 of oxygen; in its vitrification it loses a little oxygen, so as to contain not more than 11 of oxygen in 100 parts.

Zinc is scarcely sensibly acted on by water at a low temperature, but at a temperature approaching to ignition, decomposes it, attracting oxygen.

It is oxidated and dissolved with facility by the greater number of the acids. Sulphuric acid, in its concentrated state, requires the aid of heat. When diluted, it acts on the metal rapidly in the cold, enabling it to decompose the water, and hence the solution is attended with a copious production of hydrogen gas. The solution, when concentrated, is of a thick consistence, and affords in a short time slender prismatic crystals of sulphate of zinc. This crystallized salt consists of 40 of oxide, 20.5 of acid, and 39 of water. It is soluble in three times its weight of water at 60°, and in its own weight at 212°. The white vitriol of the shops is a sulphate of zinc not crystallized. It is prepared on a large scale from sulphuret of zinc, calcined, moistened, and exposed to the action of the air; the zinc is oxidated, the sulphur is converted into sulphuric acid, and the materials, by lixiviation, afford the sulphate which, by evaporation, is obtained in the state of a white granular mass; it generally has a sensible impregnation of iron.

Nitric acid is decomposed by zinc with great rapidity;

by using a dilute acid, a solution is obtained, which, by evaporation and cooling, crystallizes in slender prisms, deliquescent, and readily soluble both in water and alkohol.

Muriatic acid likewise dissolves this metal rapidly, by enabling it to attract oxygen from the water, and combining with the oxide. The solution becomes gelatinous on evaporation, without affording crystals; and when the dry mass is urged by heat, it is partly sublimed, partly decomposed. Phosphoric acid likewise dissolves zinc, by enabling it to decompose water so as to be oxidated; and this solution does not crystallize, but rather becomes gelatinous on evaporation. Even fluoric acid, which acts on few of the metals, causes the oxidation of zinc by water, and dissolves the oxide. Boracic acid, combined with the oxide by a double affinity, forms an insoluble compound. Carbonic acid, combined with water, dissolves it in small quantity.

The salts of zinc are decomposed by the alkalis and earths. If an excess of alkali be added, the precipitate is re-dissolved, and on this is founded a method of analyzing brass, which is an alloy of zinc and copper, the brass being dissolved in diluted nitric acid, the solution being decomposed by an alkali, and the precipitate, which consists of the oxides of zinc and copper, after being dried and weighed, being submitted to the action of solution of potash, by which the oxide of zinc is dissolved, while the oxide of copper remains undissolved. The fixed alkalis even act on metallic zinc, promote its oxidation by water or atmospheric air, and dissolve the oxide.

This metal, having so strong an attraction to oxygen, decomposes the greater number of the metallic salts, precipitating the metal which is their base in its metallic form.

It is soluble in small proportion in hydrogen gas. With carbon it does not combine in any considerable quantity; but the zinc of commerce, during its solution in diluted sulphuric acid, deposites a black powder, which has been supposed to consist chiefly of carbonaceous matter. Neither can zinc be united with sulphur, though the compound exists in nature. When oxidated, however, it unites with sulphur, forming a compound of a brown colour, and volatile. The alkaline sulphurets do not dissolve it. Sulphuretted hydrogen throws down a white precipitate from the solutions of its salts. With phosphorus it combines, forming a compound of a white colour, with metallic lustre, malleable, and which burns when heated with the admission of the air. Phosphorus unites too with oxide of zinc, the compound being volatile, and being capable of being obtained by sublimation in needle-like crystals of a white or bluish colour, with metallic lustre, and highly inflammable.

Zinc combines in general with the other metals. It impairs, even when added in very minute quantity, the ductility of gold and silver, rendering them also more hard. With quicksilver it forms a granular mass, which, when solid, can be crystallized. With copper, a series of alloys are formed, the most extensively used of any of the compound metals. The combination is not easily formed directly, owing to the volatility of the zinc; it is therefore usually effected by the process named cementation, copper-plates being stratified with calamine in powder mixed with charcoal, and exposed to the necessary heat; the zinc of the calamine is reduced by the charcoal abstracting the oxygen with which it is united, and unites with the copper; and this alloy being fusible, can be combined easily with additional proportions of copper or zinc. Brass is of these alloys the one which contains the largest quantity of zinc, the proportion being one to three of copper; it has the advantage, from being more fusible than copper, of being more easily cast, and it is less liable to tarnish or rust. With a larger proportion of copper, the colour approaches more to red; pinchbeck, tombac, and princes metal, are alloys of this kind. Zinc does not easily combine with iron, from the very high temperature required to melt the iron; but when iron plates are immersed in melted zinc, the metals enter into combination at the surface. It combines easily with lead and with tin, forming alloys harder than these metals.

It is principally in the formation of the alloys with copper that zinc is employed; since the discovery of the practicability of extending it in thin sheets, it has also been proposed to substitute it for some of the purposes to which lead is applied. Some of its preparations are employed in medicine.

CHAP. XIV.

OF NICKEL.

Cronstedt discovered this metal, having extracted it from its principal ore, the kupfer-nickel of mineralogists, in which it exists combined with arsenic, and a small portion of sulphur. It had usually been ranked, from its brittleness, among the semi-metals; but more recent researches, particularly those of Richter, have shewn that this brittleness is generally owing to the presence of arsenic, and that when obtained free from alloy, it is both ductile and malleable. It is extracted from the kupfer-nickel by calcining the ore to expel the volatile matter; the residual substance is mixed with twice its weight of black flux, and is melted by applying the intense heat of a forge; a metallic button is thus obtained, composed of the nickel alloyed with small portions of other metals. These it is difficult to abstract entirely, and complicated processes are therefore required to obtain nickel perfectly pure.

When obtained in a state of purity, it is of a white colour intermediate between that of silver and tin, with considerable lustre; in its usual state the colour has a reddish tint; it is hard, but has so much malleability as to be capable of being forged into very thin plates: its specific gravity is 8.6. It is very sensibly magnetic, a property which had been supposed to depend on the presence of iron. But it appears to be sufficiently established that it belongs to nickel itself, for instead of becoming weaker as the metal is purified, it becomes stronger, and at length is so strong, that if it arose from the presence of iron, it would be necessary to suppose that the iron amounts to one half its weight, though at the same time no traces of it are discoverable by chemical tests. The effect of the magnet on pure nickel is little inferior to that on iron; it can also be rendered magnetic, and magnetic needles have been constructed of it, which have the advantage of not being liable to rust.

Nickel is extremely infusible; it is imperfectly agglutinated even in the heat which melts malleable iron. When submitted to a high temperature under exposure to atmospheric air, it is oxidated, though with difficulty; by submitting it to heat mixed with nitre, its oxidation is effected with more facility. Its oxide is of an apple-green colour, and is obtained of the same colour by precipitation from some of its saline combinations. This is the oxide at the *minimum* of oxidation; when exposed to a continued red heat, or to the action of oxy-muriatic acid, it passes to a higher state of oxidation, becomes of a black colour, and when acted on by acids, is reduced again to a lower state of oxidation, a portion of oxygen being expelled.

Nickel is oxidated and dissolved by the acids; its salts are usually of a green colour. Sulphuric acid requires the aid of heat; and by evaporation of the solution, crystals of a pale green colour are obtained. Nitric acid forms a solution of a rich green colour, and rhomboidal crystals of the same colour are formed on evaporation. Muriatic acid acts more weakly on the metal, but dissolves its oxide, and likewise affords crystals of the same colour. Nitro-muriatic forms the same salt with more facility. Phosphoric acid scarcely combines even with the oxide. Fluoric acid dissolves it. Boracic acid does not directly combine with it, but the combination may be effected by the exertion of a double affinity. Carbonic acid is united with the oxide by a similar method; the carbonate, of an apple-green colour, is decomposed by heat.

The salts of nickel are decomposed by the alkalis and earths, and precipitates of a green colour thrown down. When the alkali is added in excess, the precipitate is redissolved. The pure oxide is likewise soluble in the alkaline solutions; the solution in liquid ammonia is of a rich blue colour, similar to that of copper in the same alkali; but what has been pointed out as very characteristic of nickel, is that the colour gradually changes to a purple, and lastly to a violet; the violet, by the addition of an acid, is changed to a green; but by again adding ammonia, the blue colour is restored. An effect rather singular, is the precipitation of the oxide of nickel from liquid ammonia by potash or soda.

Nickel combines with sulphur by fusion, forming a compound of a yellow colour, hard and brittle; with phosphorus it unites; the compound is of a white colour, with metallic lustre, and has a crystalline texture.

With the other metals it forms alloys, but as the nickel has been employed in their formation in its usual impure state, their properties are scarcely be considered as known. Its oxide combines by fusion with the vitrifiable earths, and forms glasses of a hyacinthine colour.

CHAP. XV.

OF COBALT.

The ores of this metal had been long employed, from a property belonging to it, of giving a blue colour to glass. The metal itself was first extracted by Brandt, and its properties were examined by Bergman. It occurs in nature alloyed with arsenic, nickel, and other metals, and mineralized likewise by oxygen, and by arsénic acid. It is obtained after the ore has been roasted and calcined, in the state of an oxide impure from the presence of other metallic oxides. This, with an intermixture of siliceous earth, forms the zaffre of commerce. When mixed with thrice its weight of black flux, a little sea-salt and oil, and urged with an intense heat, it is reduced, and affords metallic cobalt, alloyed, however, with portions of arsenic, nickel, and generally of iron. To free it from these is difficult, and very complicated processes are required.

When cobalt is obtained in a state of purity, it is of a white colour inclining to grey, and if tarnished to red, with moderate lustre; its fracture is compact; it is hard and brittle; its specific gravity is 7.8. Like nickel, it is sensibly magnetic; and this even as powerfully as iron, and when it has been purified, so that no traces of that metal are discoverable by tests, by which a minute portion of it intentionally added was detected.

Cobalt requires a very intense heat to melt it; its fusing point has been estimated at 130 of Wedgwood's scale. At a temperature much inferior to this, it suffers oxidation from the action of the air: the oxide is of a deep blue colour; a precipitate of a similar colour is thrown down from its saline compounds by the alkalis. This, when exposed to the air in a humid state, appears to absorb oxygen; it assumes an olive colour, and when heated in contact with the air, it becomes brown, and at length nearly black. The oxide at the *minimum* has been stated by Proust to contain 19 of oxygen, that at the *maximum* 24 of oxygen in 100 parts.

The acids oxidate cobalt, or combine with its oxides. When sulphuric acid is boiled on it, sulphurous acid is disengaged, and a saline matter obtained of a reddish colour, which is sulphate of cobalt. This, when dissolved, affords, by evaporation, acicular crystals of a reddish tinge. Nitric acid oxidates and dissolves the metal in the cold; the solution is of a red colour, and affords on evaporation minute prismatic crystals, which are deliquescent. Muriatic acid, to act on cobalt, requires the application of heat; it dissolves the oxide more readily, forming a solution of a reddish tinge, and which by evaporation affords needle-like crystals of the same colour. Phosphoric acid forms with its oxide a red-coloured solution, which, when saturated, is turbid. Fluoric acid gives a gelatinous solution. Boracic and carbonic acids are combined with it by the process of double affinity, and form compounds of sparing solubility.

The solutions of the salts of cobalt afford a sympathetic ink, lines traced with them on paper being invisible when cold, but becoming green when heated, the green colour disappearing again as the paper cools. The solution usually employed for this purpose, is prepared by dissolving one part of zaffre in two of diluted nitric acid, with the aid of heat, adding to it muriate of soda one part, and diluting it with twenty parts of water. A red sympathetic ink is said to be formed by dissolving pure oxide of cobalt in pure acetic acid; and a purple one by dissolving it in distilled vinegar, and adding to the solution muriate of soda.

The salts of cobalt are decomposed by the alkalis and earths, precipitates being thrown down of a red tinge; or, according to Thenard, if the cobalt is perfectly pure, of a blue colour. By an excess of alkali, they are re-dissolved, particularly when ammonia is employed, and the oxide is at the minimum of oxidation. It vitrifies with siliceous earth, forming a substance of a deep blue colour, the smalt of commerce.

Cobalt does not combine with sulphur by fusion, but is dissolved by the alkaline sulphurets. With phosphorus it unites, forming a compound of a white colour and metallic lustre, brittle, and of a striated texture.

It forms alloys with a number of the metals, but none applied to any use. Gold and silver it renders quite brittle. It does not amalgamate with quicksilver. With copper it forms an alloy, white, hard, and brittle; with iron, one of a close grain, and very hard. It combines with lead in different proportions, the alloy, when the proportion of cobalt is considerable, being brittle and hard: with tin it forms a compound metal, of a violet colour, and close grain. It does not combine with zinc.

Cobalt is principally employed to give a blue colour to glass, a portion of its oxide being fused with the glass. Its oxide is applied by the proper flux to give the blue colour in painting on porcelain.

CHAP. XVI.

OF MANGANESE.

THIS metal occurs in nature in the state of oxide, and this oxide had been used in some arts, particularly in the manufacture of glass, to render it free from colour, before its nature was known. Scheele and Bergman, from an examination of it, inferred that it is the oxide of a peculiar metal, and this metal has since been procured in its pure form. The process, however, is extremely difficult, from the intense heat that is required. The oxide reduced to powder, is made into a paste with a small quantity of oil and charcoal, and being imbedded in charcoal powder, is exposed to the most intense heat which the most powerful furnace can raise. To obtain it more free from iron, the oxide may be previously dissolved in diluted nitric acid, adding a little sugar, which is necessary to promote the solution; this solution is decomposed by carbonate of soda; the white precipitate of carbonate of manganese being dried, is decomposed in the manner above described. The metal can scarcely be obtained but in small globules. In this state it is of a greyish-white colour, with moderate lustre, which tarnishes, however, on exposure to the air; its texture is granular, it is brittle and hard, its specific gravity is 6,8. Some of the globules split and fall to powder on exposure to the air, while others retain their metallic form; the change in the former has been ascribed to the presence of a portion of carbon, which absorbing oxygen, the cohesion is subverted.

When metallic manganese is exposed to heat in contact with the air, it passes rapidly through different stages of oxidation, becoming grey, yellow, red, brown, and at length black; this black oxide being the metal at the *maximum* of oxidation, and the same with the native oxide. By precipitation from some of its saline compounds, an oxide nearly white is obtained, in which the metal appears to be at the *minimum* of oxidation; the white oxide, according to Bergman, consists of 80 of manganese, and 20 of oxygen; the black oxide, according to Fourcroy, of 60 of manganese, and 40 of oxygen, and the series between these is probably indefinite. The white oxide absorbs oxygen when exposed to the air, especially when heated a little; the black oxide, on the contrary, at a temperature above ignition, gives out a portion of oxygen gas, the quantity being larger as the heat is more intense;

it is thus converted into oxides of different shades of brown and grey. The affinity of the metal to oxygen becoming more powerful as the decomposition proceeds, from the increase in its relative quantity, it is at length capable of counteracting the effect of the elevated temperature, and it is scarcely possible, by any intensity of heat, to reduce it to the state of the white oxide.

Manganese being not easily procured in its metallic form, its relations to the acids have been examined principally in their actions on its oxides; and these display extremely well the effects of particular degrees of oxidation on these relations. In general it appears, that the black oxide is too highly oxidated to combine with the acids; and hence the necessity of its de-oxidation in establishing these combinations.

Thus, when sulphuric acid is brought to act on the black oxide, by applying a moderate heat, it does not directly combine with the oxide, but decomposes it, a considerable portion of its oxygen is separated, and assumes the elastic form, and with the oxide thus reduced in its degree of oxidation, the acid combines. This sulphate of manganese is soluble in water; when obtained neutral, it becomes gelatinous, forming at the same time small crystals. The alkalis throw down from it a reddish-yellow precipitate. The oxide existing in it appears to be not altogether at the minimum of oxidation. The salt formed by the action of sulphuric acid on metallic manganese, is rather in that state; it is colourless, affords by evaporation rhomboidal crystals, and gives a white precipitate when decomposed by the alkalis. It is obtained in a similar state, by digesting the black oxide with sulphuric acid, and a portion of carbonaceous matter, as sugar, which attracts the excess of oxygen from the salt. Sulphurous acid forms a similar combination.

Nitric acid does not dissolve the black oxide of manganese, but if any substance is added which attracts oxygen from the acid, this enables it to re-act on the oxide, and reduce its state of oxidation, and then the solution is effected. A little alkohol or sugar has this effect, or, as Scheele shewed, exposing the acid with the oxide to the solar rays. The solution formed in these cases is colourless, and when decomposed by the alkalis, gives a white precipitate.

Muriatic acid is equally incapable of combining directly with the black oxide, but, according to the theory usually given of its action, it de-oxidates it, one portion of the acid passes to the state of oxy-muriatic acid, which escapes in the elastic form, while another portion of the acid combines with the oxide thus reduced in the degree of oxidation. On this depends, indeed, the conversion of muriatic into oxy-muriatic acid, by the black oxide of manganese. The muriate of manganese is colourless, and affords by evaporation a soft deliquescent mass; when decomposed by the alkalis, it gives a yellowish-white precipitate.

The phosphate, fluate, and borate of manganese, are most easily formed, by adding to the solution of the muriate or nitrate of the metal, a solution of any neutral salt containing any of these acids; being insoluble, they are precipitated. Carbonate of manganese may be formed by a similar process; and a portion of the oxide is even dissolved by water impregnated with carbonic acid.

The salts of manganese suffer decomposition from the alkalis, which precipitate the oxide retaining perhaps a little of the acid with which it is combined. They are not decomposed by the inflammables or the other metals, a proof of the strength of affinity of manganese to oxygen.

The fixed alkalis combine with black oxide of manganese, when their mutual action is promoted by heat. The compound is soluble in water, and during its solution exhibits rapid changes of colour, the liquor being first green, then changing to a purple and violet, and becoming after some time colourless: it is also rendered colourless at once by a few drops of nitric acid. These changes are probably owing to rapid changes of oxidation; the compound to produce them is best obtained by calcining a mixture of one part of the black oxide with three parts of nitre.

Oxide of manganese combines with those earths capable of vitrification, and with their vitrifiable compounds, and communicates to the glasses they form a violet tinge; it communicates the same colour to borax, and other vitrifiable salts.

Manganese cannot be combined with sulphur; the oxide, heated with sulphur, forms a yellowish-green mass, which, when acted on by acids, produces sulphuretted hydrogen. It unites with phosphorus, and forms a compound of a white colour and metallic lustre, of a granular texture, brittle and fusible.

Manganese, from its infusibility, cannot be combined with many of the metals. It shews a considerable affinity to iron, occurring frequently combined with it in nature, and being capable of being combined with it artificially, when it forms an alloy white and brittle: it is contained too in those ores of iron best adapted to the fabrication of steel, and is supposed to improve the quality of steel.

The metal is applied to no use in its metallic form. The black oxide is employed by the chemist, as affording by the most economical process oxygen; and in the formation of some chemical compounds, particularly the oxy-muriatic acid, it is used with the same view. It has long been used in the art of glass-making, to counteract the green tinge communicated by the iron contained in the materials, an effect it produces by yielding oxygen to the oxide of iron, and bringing it to a high degree of oxidation; in a larger quantity added to glass, it gives a purple colour. It is also used to give a black colour to earthen ware.

CHAP. XVII.

OF ARSENIC.

The name Arsenic is in common language applied to the oxide of a metal, to which in the chemical nomenclature it is appropriated. This oxide, obtained by sublimation from certain metallic ores, particularly those of cobalt, was known long before the method of obtaining the metal from it had been discovered. This was made known by Lemery and Schroeder. It is sufficiently simple, consisting merely in mixing the oxide with twice or thrice its weight of the black flux, and exposing the mixture in a retort or glass tube, or in a crucible to which another is adapted, to a heat gradually raised to ignition; the oxygen of the oxide is abstracted by the carbonaceous matter, and the metallic arsenic is sublimed.

This metal is of a bluish-grey colour, with considerable lustre, which, however, is soon tarnished from exposure to the air. Its texture is distinctly broad striated, and it is extremely brittle, so as to be easily reduced to powder. Its specific gravity has been stated at 5.763, and also at 8.310.

It is so volatile that its fusion cannot easily be accomplished. It passes into vapour when heated to about 383° of Fahrenheit. When condensed slowly, it forms octohedral crystals. In the state of vapour it has a strong and peculiar smell, which has often been compared to that of garlic.

In volatilizing, if the atmospheric air is admitted, it is oxidated rapidly, a white vapour being produced consisting of the oxide; if the heat is raised somewhat higher, the metal burns with a dull blue flame, and the production of the same oxide. This oxide has peculiar properties. It is not, like the greater number of oxides, insipid, and insoluble in water; its taste is on the contrary sharp and acrid, and it is so soluble that it requires not more than 80 parts of cold and 15 of boiling water for its solution; the latter solution affording on cooling, crystals in the form of four-sided prisms or octohedrons. It combines too with the alkalis, and even reddens the infusion of litmus. Hence it has been regarded rather as an acid than an oxide, and has received the name of arsenious acid. Yet it is on the whole more analogous to oxides in a high state of oxidation, for it is incapable of neutralizing the alkaline properties, while it combines with the acids, and produces with them neutral compounds. It is this substance which is the most virulent of the metallic poisons. It consists of 75.2 of arsenic, and 24.8 of oxygen. As obtained by sublimation, it is in the form of a dense cake, but it is reduced to powder for the purposes to which it is applied in some of the arts.

Arsenic is capable of acquiring unequivocal acid powers by a higher degree of oxygenation. This is effected by distilling nitrous acid from the white oxide, the acid yielding the requisite proportion of oxygen; or with more facility, by dissolving the oxide in muriatic acid with the assistance of heat, adding to this nitric acid, and distilling until the production of nitrous vapours cease. By continuing the application of the heat, and raising it at the end of the process to redness, the arsenical acid is obtained in a concrete form. The oxide, in its conversion to the acid, increases nearly one-seventh in weight. The acid consists of 64 of arsenic, and 36 of oxygen.

The oxide of arsenic combines with the different acids, forming compounds which are not easily obtained in the neutral state. The same compounds are in general produced by the action of the acids on metallic arsenic, the acid first yielding oxygen, and then combining with the oxide.

Sulphuric acid oxidates the metal when its action is promoted by heat; it also dissolves the oxide when boiled on it, forming a compound which, as the solution cools, is deposited in crystalline grains.

Nitric acid oxidates metallic arsenic. When much diluted, it dissolves the oxide, and the compound being of sparing solubility, is deposited. When concentrated, it yields oxygen to it, and partially converts it into arsenic acid.

Muriatic acid, digested with heat on metallic arsenic, causes its oxidation by the decomposition of water; the hydrogen disengaged has a very fœtid odour, from a portion of oxide which it holds dissolved. The acid boiled on oxide of arsenic dissolves one-third of its weight nearly, forming a salt of sparing solubility. A muriate of arsenic is obtained still more concentrated, by distillation from a mixture of corrosive muriate of mercury and metallic arsenic, the oxygen and acid being transferred from the quicksilver to the arsenic; the product is partly liquid, partly congealed; it emits acrid vapours, is deliquescent, but, by the affusion of water, is decomposed. By spontaneous evaporation, it deposites pellucid crystals, which are sparingly soluble in water. Oxy-muriatic acid gas inflames metallic arsenic, and converts it into the oxide or acid.

The other acids scarcely act on metallic arsenic, but combine with its oxide, and form compounds of sparing solubility.

Oxide of arsenic combines with the alkalis. The combinations with the fixed alkalis are formed by fusion; and even the solution of the alkali, boiled on the oxide, dissolves a large portion of it, the solution, when concentrated, being viscid, of a brown colour, and unpleasant odour. Ammonia likewise dissolves a quantity of the oxide; and it combines in the dry way, by the application of heat, with lime and some of the other earths.

Arsénic Acid has all the most important acid properties. It is abundantly soluble in water, requiring only six parts for its solution at 60°, and not more than two parts at 212°; its taste is sour; it reddens the vegetable colours, and combines with the alkalis, earths, and metallic oxides, forming in the due proportion neutral compounds. By slow evaporation, it may be obtained in small irregular crystals. When evaporated to dryness, it forms a white solid mass, which, by raising the heat to ignition, is melted, and forms a translucent glass. By a continuance of the heat, it is partially decomposed, oxygen being expelled; and it is decomposed with facility by heating it with inflammable substances, being reduced to the metallic state.

Arsénic acid combines with the alkalis, forming salts soluble and crystallizable. They may be formed by direct combination, and also by an indirect method which has been generally followed, exposing a mixture of the white oxide of arsenic with any of the alkaline nitrates, to heat, continuing this as long as any red vapours are disengaged. The nitric acid is decomposed, yielding oxygen to the oxide, so as to convert it into arsénic acid, with which the alkaline base of the nitrate combines. The arseniate thus formed is obtained pure by solution and crystallization. The arseniate of potash, formed by this process, forms large regular crystals, tetraedral prisms, having generally an excess of acid, to which the regularity of its crystallization is owing, the perfectly neutral salt not crystallizing so regularly, and being deliquescent. The arseniate of soda crystallizes in hexaedral prisms, arseniate of ammonia in rhomboidal prisms.

Arsénic acid combines with the earths, forming compounds of very sparing solubility, but which are rendered more soluble by an excess of acid.

It acts on several of the metals, yielding oxygen to the metal, and being thus reduced to the state of oxide. When the metal is previously oxidated, the arsénic acid enters into direct union with the oxide; but these combinations, presenting no important results, scarcely require to be individually noticed.

Metallic arsenic is dissolved by hydrogen gas. This compound is formed when zinc is acted on by arsénic acid, or from the mutual action of diluted sulphuric acid, zinc, and oxide of arsenic. It has the peculiar odour which arsenic has when in the state of vapour, and is heavier than pure hydrogen gas. When detonated with atmospheric air, it deposites a film of metallic arsenic; when detonated with oxygen gas, the arsenic is deposited in the state of oxide. It is also decomposed by nitric oxide gas and oxy-muriatic acid gas, the arsenic being precipitated either in its metallic or oxidated state, according to the proportions in which the gases are mixed. Even nitrous acid decomposes it with detonation; and sulphuric and nitro-muriatic acid precipitate from it a metallic film.

From its decomposition by nitric acid, it is inferred to consist of 10.600 of arsenic, and 0.219 of hydrogen.

Arsenic unites with sulphur by fusion or by sublimation, forming compounds of a red or yellow colour, according to the proportions. Its oxide, heated with sulphur, suffers decomposition, and similar compounds are produced. With phosphorus arsenic forms a compound of a black colour and metallic lustre, which tarnishes and oxidates on exposure to the air.

Arsenic combines with nearly all the metals, the combination being effected with most facility by exposing to heat a mixture of oxide of arsenic and the black flux, with the metal with which it is designed to be combined. The ductile metals it in general renders brittle, and to those that are refractory in the fire it communicates fusibility. Few of its alloys are applied to use. That with copper is of a white colour, and receives a fine polish; and hence it has been used instead of pure copper in forming silver-plating, but it has the disadvantage of tarnishing on exposure to the air. Oxide of arsenic exerts affinities to some of the other metallic oxides, and hence decomposes some of the metallic salts. The precipitate which its solution in potash throws down from a solution of sulphate of copper, is a combination of this nature; it is of a bright green colour, and is used as a pigment.

A part of the chemical history of arsenic is that relating to the tests by which it is detected, as, from being so active a poison, this is occasionally the subject of judicial investigation. The most decisive is, reducing a little of the oxide, by exposing it mixed with twice its weight of the black flux, or of charcoal powder, in a coated glass tube lightly stopped, to a low red heat cautiously raised; a metallic crust of a grey colour and great brilliancy is obtained on the sides of the tube. The only disadvantage of this test is, that it cannot well be performed on a smaller quantity than several grains. 2*d*, A little of this reduced metal, when put on a red-hot iron, is volatilized, and the vapour, in exhaling, has a peculiar odour, approaching to that of garlic. The oxide is also volatilized by the same degree of heat, forming a white smoke; and if it has been previously mixed with a minute quantity of oil, it will, in evaporating, give the garlic odour: this odour, it is to be remarked, however, is not very evident where a small quantity is employed, and is disguised by the intermixture of vegetable and animal substances. 3*d*, If a little of the reduced metal, or a small quantity of the oxide made into a paste with charcoal and oil, be placed between two copper pieces, if these are pressed together, secured by wire, and exposed to a red heat in a charcoal fire for a quarter of an hour, the surface of the copper will be permanently whitened, so that, on removing the adhering matter, and rubbing it with a little chalk, it will have nearly the appearance of silver, owing to the alloy of the copper and arsenic. 4*th*, If a little of the oxide be dissolved in warm water, with three times its weight of carbonate of potash, the solution, on being added to a solution of sulphate of copper, throws down a precipitate of a lively grass-green colour. To render this more evident and certain by contrast, a little of a solution of carbonate of potash alone ought to be added to the solution of sulphate of copper;

the precipitate it forms is of a bluish-green, and the difference is sufficiently evident when they are compared as they ought to be in the light of day. The same experiment may be made with any remaining portion of the liquid that has been the vehicle of the poison, or on the liquid found in the stomach, and freed by filtration from the substances diffused through it.

5th, Mr Hume has lately given another test,—that of nitrate of silver, which, added to a solution of so small a quantity of white oxide of arsenic as one grain, with an equal weight of carbonate of soda in ten or twelve ounces of boiling distilled water, produces instantly a bright yellow precipitate.

CHAP. XVIII.

OF BISMUTH.

Bismuth is a metal of a white colour, with a yellowish tinge, liable to tarnish and become iridescent from exposure to the air; its texture is distinctly foliated; it is not very hard, is quite brittle, and has a specific gravity of 9.8.

It is very fusible, melting at 460° or 480°. It crystallizes easily by slow cooling. When in fusion, if the air is admitted, its surface is soon covered with a greenish-grey powder from oxidation. If it be exposed to a stronger heat, it burns with a small flame, and forms a yellow powder more highly oxidated. These oxides, by a powerful heat, are fused into transparent glasses.

Bismuth is oxidated and dissolved by the acids; its salts are in general decomposed by the affusion of water.

Sulphuric acid boiled on it is decomposed, sulphurous acid gas being disengaged, and oxide of bismuth remaining combined with a portion of sulphuric acid. By the action of water this is resolved into a sub-sulphate and super-sulphate, the latter affording acicular crystals on evaporation.

Nitric acid is rapidly decomposed by bismuth, the temperature rises, and dense red vapours are disengaged; the metal being so highly oxidated that it retains combined with it little of the acid. By using a diluted acid, a more perfect solution is obtained, which by evaporation affords rhomboidal crystals. By the affusion of water a white precipitate is thrown down, the Magistery of Bismuth, as it has been named, which is a sub-nitrate. When the solution is decomposed by a solution of tartrate of potash, a very white precipitate is obtained, which forms the paint sometimes used for the complexion, known by the name of Pearl-white.

Muriatic acid scarcely acts on metallic bismuth, but it combines with its oxides; and the solution, when concentrated by evaporation, forms a thick soft mass, which is liquified by heat, and congealed by cold. The metal in filings inflames when projected into oxy-muriatic acid gas.

Phosphoric acid forms with oxide of bismuth a compound which is insoluble, and which melts before the flame of the blow-pipe into a glass. Fluoric acid forms with it a solution of a sweetish taste. Boracic and carbonic acids, in combining with it by double affinity, form insoluble compounds.

All the salts of bismuth are decomposed by the alkalis, and the precipitate which is thrown down is dissolved by boiling in a solution of potash or soda, or by digestion in liquid ammonia.

Bismuth combines with sulphur by fusion, and forms a compound of a grey colour and metallic lustre, which is easily melted, and when allowed to cool slowly, forms a mass composed of tetraedral prisms. Sulphuretted hydrogen tarnishes the metal, and either pure or in the state of hydro-sulphurets or sulphuretted hydro-sulphurets, throws down from solutions of its salts very dark-coloured precipitates; by this action it forms with these solutions a subtile sympathetic ink.

Bismuth does not unite either with phosphorus, carbon, or hydrogen.

It combines by fusion with the greater number of the metals, and in general communicates brittleness and fusibility. This property, with regard to fusibility, is well displayed in the formation of what is named the fusible metal, which consists of eight parts of bismuth, five of lead, and three of tin, and which melts at 212°, a degree of fusibility much greater than that of any of the metals of which it is composed. The addition of a little quicksilver renders it still more fusible, and a composition of this kind is used to coat the internal surface of glass globes. To quicksilver alloyed with lead, bismuth added in small quantity, by increasing the fusibility, communicates a mobility equal to that of pure quicksilver, and hence it is used in adulterating that metal. It adds too to the fusibility of tin, the alloy of equal parts melting at 280. In a smaller proportion it adds to the hardness of tin, and hence it is used in the formation of pewter. An alloy of equal parts of tin, bismuth, and quicksilver, forms a compound of a flaky brilliant appearance, named Mosaic Silver, sometimes applied to ornamental purposes. It is principally in the formation of these alloys that bismuth is employed.

CHAP. XIX.

OF ANTIMONY.

THE native sulphuret of this metal is the substance to which the name antimony was originally applied; but the name is now appropriated to the metal, and the other in commerce is distinguished by the epithet crude antimony. It is from this sulphuret that the metal is extracted: the usual process is to fuse it with iron-filings, with the addition of a little nitre; the sulphur combines partly with the iron, partly with the potash of the nitre, and the metal is run out.

Antimony is of a light bluish-grey colour, with a lustre not much liable to tarnish; its texture is very distinctly plated; its hardness is moderate; it is quite brittle, so as to be easily beat to powder. Its specific gravity is 6.7.

At a heat a little above ignition, antimony melts, and in cooling it assumes a crystalline arrangement easily observed on the surface of the mass, and in its structure. At a full white heat it is volatilized.

Heated under exposure to the air it is oxidated; and if the heat be high, the oxide is volatilized, passing at the same time to a higher state of oxidation, and condensing in acicular crystals; the oxidation, if rapid, is attended with a weak flame. By deflagration with nitre, it is also obtained at a high state of oxidation, the oxide remaining combined with a portion of the alkali of the nitre; and it exists in various degrees of oxidation in its saline combinations. Thenard has distinguished not less than six oxides of this metal. Proust has supposed there are only two, one containing 18.5 of oxygen in 100 parts, the other containing 23. It is probable, in conformity to the law which appears to regulate the combination of metals with oxygen, that the degrees of oxidation are numerous, and even indefinite, when not rendered uniform by the operation of external circumstances.

Antimony is acted on by the acids. Sulphuric acid boiled on it is in part decomposed, sulphurous acid being disengaged, the oxidated metal combines with another portion of the acid, forming the sulphate of antimony, which cannot be crystallized, but by evaporation forms a mass which is very deliquescent, and is decomposed by water.

Nitric acid oxidates antimony, and if not too highly concentrated, forms a solution which affords by evaporation a deliquescent salt.

Muriatic acid acts on antimony very slowly, but combines easily with its oxides. The nitro-muriatic acid dissolves it still more readily, and when composed of five parts of muriatic, and one of nitric, affords a perfect solution, which, after evaporation of the superfluous water, may be distilled by the application of heat; the muriate comes over of a thick consistence, and melts on the application of a very moderate heat. From these properties, it was termed Butter of Antimony by the older chemists. Various indirect methods of obtaining it were employed. The most common was to mix antimony with corrosive muriate of mercury, and expose it to heat; the antimony attracts the oxygen and muriatic acid from the mercury, and the muriate of antimony distils over. Another process given in the Pharmacopœias, is to mix one part of brown oxide of antimony, and one part of sulphuric acid, with two parts of muriate of soda, and apply heat to the mixture in a retort; the muriatic acid is disengaged, and combines with the oxide, forming the muriate which is sublimed. This salt is extremely corrosive, it liquifies by exposure to the air, from attracting a quantity of water sufficient to dissolve it; but when water is poured upon it, it is decomposed, the water, acting by its quantity, abstracting a portion of the acid, and precipitating sub-muriate of antimony.

The other acids, though unable to dissolve antimony, combine with its oxides. Of these salts, the only one of any importance is a ternary compound of oxide of antimony, tartaric acid, and potash. This has been long employed in medical practice, under the name of Emetic Tartar, as one of the mildest and most manageable of the antimonial preparations. Various processes have been followed for its preparation; that now given in the Pharmacopœia of the Edinburgh College, is to boil three parts of the brown oxide, obtained by deflagrating sulphuret of antimony with nitre, with four parts of super-tartrate of potash, in thirty-two parts of water for half an hour; the solution, when strained, is set aside to crystallize. The excess of tartaric acid in the super-tartrate dissolves a portion of the antimonial oxide, and the crystallized salt is a triple compound of the oxide, the acid, and part of the alkali, the proportions, according to Thenard's analysis of it, being 38 of oxide, 34 of acid, 16 of potash, and 8 of water of crystallization.

The alkalis do not act on antimony, but they combine with some of its oxides. When deflagrated for example with nitre, the oxide remains in combination with the potash of the nitre. If this be submitted to the action of water, it is resolved into two compounds, one having an excess of alkali which is dissolved, the other with an excess of oxide which remains undissolved. The latter has been named Calcined, or Diaphoretic Antimony.

Antimony combines with sulphur by fusion, and forms a compound similar in appearance to the native sulphuret. Sulphuret of antimony has some peculiar chemical relations which require to be pointed out, as in this state antimony has been more frequently submitted to experiment by the chemists than in its pure form, and several preparations are obtained from it, important from their medicinal use.

When native sulphuret of antimony is exposed to heat, sulphureous fumes arise; and if the heat is continued and gradually raised, the metal is converted into a grey oxide, which retains a portion of sulphur in combination. If this be exposed to an intense heat, it melts and forms a transparent glass of a dark brown or reddish colour, the vitrified oxide of antimony, as it is named; it generally contains a little silex from its action on the crucible, in which it is melted.

The metal in the crude antimony is likewise oxidated by deflagrating it with nitrate of potash. If equal parts of the sulphuret and nitre are deflagrated together, the greater part of the sulphur is converted into sulphurous acid, which is partly dissipated, and partly combines with the potash of the nitre, and the antimony is imperfectly oxidated, the oxide, which is of a brown colour, having combined with it a small quantity of sulphur which had escaped deflagration, and a minute portion of hydrogen, probably derived from the water the nitre contained. When a larger quantity of nitre is employed, the oxidation is more perfect, and the white oxide is formed, which has been already noticed.

When sulphuret of antimony is fused with an alkali, with potash for example, and thrown into water, or when an alkaline solution is boiled upon it, part of it is found to be dissolved. If the liquor is strained while hot, a red powder is deposited, which was named by the chemists Kermes Mineral. If an acid is added to the solution while warm, and previous to this deposition, it combines with the alkali, and a precipitate of a reddish yellow colour is formed, which used to be named Golden Sulphur of Antimony, which is now named Precipitated Sulphuret of Antimony. These two preparations are similar in their composition, being compounds of oxide of antimony, with sulphur and sulphuretted hydrogen, the antimony during the process, having been oxidated probably from the decomposition of the water by the alkaline sulphuret, and the sulphuretted hydrogen being derived from the same source. The yellow precipitate differs from the red, principally in containing a larger proportion of sulphur.

The last preparation of this kind is one that has been celebrated as an empirical medicine, James's Powder, the phosphate of antimony and lime, as it is now named, for the process for the preparation of which we are indebted to Dr Pearson. It consists in exposing first to a moderate heat in an open vessel, and then to a stronger heat in a covered crucible for two hours, equal parts of the sulphuret of antimony, and shavings of bones. The sulphur is dissipated, the metal is oxidated, the animal matter of the bones is burned out, and the phosphate of lime, which is the solid matter of the bones, remains intimately mixed, or perhaps combined with the antimonial oxide. According to Dr Pearson's analysis of it, it consists of 43 parts of phosphate of lime, and 57 of oxide of antimony, about 28 parts of this oxide being vitrified.

Antimony unites with phosphorus; the compound has metallic lustre, and is of a white colour; its fracture is lamellated. It melts, and burns with a green flame when thrown upon ignited fuel.

Antimony combines with nearly all the metals; its alloys are in general brittle, and few of them have been applied to any use. It unites with difficulty with mercury. Fused with lead, it affords a white brittle alloy, of which printing-types are cast; the compound consists of 80 parts of lead, and from 15 to 25 of antimony, with the addition frequently of a small proportion of zinc; this alloy is tolerably hard, without being brittle, and it takes a delicate impression from a mould, owing probably to the expansion which antimony suffers in consolidating from fusion. It is principally in the formation of this alloy, and in the practice of medicine, under different forms of preparation, that antimony is employed. Its oxides sometimes enter into the composition of coloured glasses, and into the formation of certain paints.

CHAP. XX.

OF TELLURIUM.

THIS is a metal of modern discovery. It occurs in nature alloyed with gold, principally in certain ores of that metal found in Transylvania; when obtained free from alloy, it is of a tin-white colour with metallic lustre, has a foliated fracture, is extremely brittle, and is one of the lightest of the metals, its specific gravity being only 6.1.

It melts easily and at a temperature a little inferior to that of ignition; and it is also easily volatilized; when heated before the flame of the blow-pipe it inflames, and an oxide is formed in vapours, having a pungent odour, which condense into a white powder. This, heated in a glass retort, melts, and forms when cold a substance of a yellowish colour, and striated texture.

Tellurium is oxidated and dissolved without difficulty by the acids. Sulphuric acid, when concentrated, acquires from it a purple colour; by dilution with water this colour is lost, as it is also from heat; and in either case the small quantity of metallic matter dissolved is precipitated. Nitric acid forms with it a colourless solution, which is not rendered turbid by water, and which, when concentrated, affords needle-shaped crystals. Muriatic acid, to which a little nitric acid has been added, affords a transparent solution, from which a white precipitate is thrown down, on the addition of water, and which, by repeated affusions of water, is dissolved. The alkalis throw down from all these solutions, precipitates of a white colour, which an excess of alkali re-dissolves. They are not precipitated by prussiate of potash: tincture of galls forms a yellow flocculent precipitate. Several metals, as zinc, iron, tin, and antimony, precipitate from them the tellurium in its metallic state, and phosphorus has the same effect.

This metal combines with sulphur by fusion, forming a lead-coloured striated substance. The alkaline sulphurets throw down dark-coloured precipitates from its solutions.

The alloys of tellurium, with the other metals, have scarcely been examined. It does not easily amalgamate with quicksilver, even when their action is aided by heat.

CHAP. XXI.

OF CHROME.

THIS metal exists in the state of an acid combined with oxide of lead in a mineral the produce of Siberia; and it has been discovered in some other metallic fossils, particularly combined with iron. It is also the colouring principle of the emerald and ruby. Vauquelin, its discoverer, gave it the name of chrome from its most characteristic property, that of assuming different brilliant colours in the combinations into which it enters.

It is extracted from the mineral which affords it, the red lead ore, by adding muriatic acid, which combines with the oxide of lead, the muriate of lead is precipitated, and the chromic acid remains in solution. It is obtained by evaporation in a dry mass, which being exposed to an intense heat in mixture with charcoal, is reduced to the metallic state. The metal is of a white colour, inclining to grey; it is very brittle, and in its fracture displays a radiated structure.

Chrome is very difficult of fusion. At a high temperature it is oxidated by the atmospheric air, its surface being covered with a green oxide. By a higher degree of oxygenation, which is effected most easily by distilling nitric acid from it repeatedly, it is brought to the state of an acid. It is then combined with about 0.40 of oxygen.

Chrome is little affected by the acids. Even nitric acid requires to be distilled from it a number of times to oxidate it fully. Nor are saline combinations of it easily formed, even when the metal has been previously oxidized.

Chromic acid has more energy of chemical action. It is very soluble in water, forming a solution of an orange-red colour, which affords by evaporation slender prismatic crystals of a ruby-red colour. The portion of oxygen producing its acidification is not retained by a strong affinity, hence it is easily reduced to the state of the green oxide. Exposure to the solar rays has this effect, as has also the action of the greater number of the metals, or ether or alkohol when either of them is boiled with it for a few minutes. Muriatic acid has a similar effect, oxy-muriatic acid gas being disengaged, and the solution assuming a beautiful green colour from the production of oxide of chrome. Even heat produces this change, the green oxide being formed when the acid is heated before the flame of the blow-pipe on charcoal, or when it is fused with borax or phosphoric acid.

This acid combines with the alkalis, earths, and metallic oxides, forming salts, many of which have very brilliant colours. The alkaline chromates are soluble and crystallizable; the colour of their solutions is orange-yellow, and by evaporation they afford crystals of the same colour. The chromate of potash crystallizes in rhomboidal prisms, that of ammonia in plates. The earthy chromates are in general sparingly soluble, and have also an orange colour.

The metallic chromates have various, and generally vivid colours; that of lead is an orange yellow, of mercury a vermilion red, of silver a carmine red, of zinc and bismuth yellow. Some of these would form very beautiful pigments, could the chromic acid be easily procured in sufficient abundance.

CHAP. XXII.

OF MOLYBDENA.

THIS metal exists in the state of an oxide or acid combined with sulphur, in a mineral similar to plumbago in appearance, to which the name of Molybdena had been given. Scheele discovered the nature of this substance, and gave the processes by which the metal is extracted. The most simple of these, and which at the same time affords the purest product, is to distil from one part of it reduced to powder five parts of diluted nitric acid to dryness, repeating this distillation three or four times with new portions of the acid. The sulphur is converted into sulphuric acid, the molybdena into molybdic oxide or acid; the former is removed by washing with water, the latter, being sparingly soluble, remains undissolved. By mere calcination, too, the sulphur of the native sulphuret may be dissipated, and the oxide or acid of molybdena obtained.

The reduction of this to the metallic state, or rather the fusion of the metal, is extremely difficult. Though reduced by exposure to intense heat in mixture with charcoal and oil, it is scarcely agglutinated, but forms merely a mass which breaks under the finger. Hielm, however, obtained it in a kind of slag, and Bucholz, after repeated experiments with the most intense heat that could be raised by the fire of a forge, succeeded in fusing it so as to obtain it in globules, and even in a mass of two drachms weight. The metal he found to be of a silvery white colour; it had no ductility or malleability, but was so hard as not to be easily broken; its specific gravity was 8.6.

Though this metal is so infusible, it is easily oxidated. Its surface becomes dull from the flame of the blow-pipe. By the continued application of a red heat, it becomes of a brownish-yellow colour, which soon changes to violet. By calcination with a higher heat, or by deflagration with nitre, it is converted into a white oxide, and at its highest degree of oxygenation acquires acid powers. Mr Hatchet concluded that it is susceptible of four degrees of oxygenation; the first forms a black oxide, the second one of a blue colour, the third one that is green, and the fourth produces the molybdic acid. The transitions through this series are best shewn in de-oxidating the acid, or its compounds, these changes being easily effected from the weak affinity with which the oxygen appears to be retained.

These varied and successive degrees of oxygenation are displayed in the actions of the acids on this metal. Nitric acid acts on it rapidly, converts it first into the blue oxide, and ultimately into the molybdic acid. Sulphuric acid boiled on it, acquires a bluish-green colour, which, by continuing the boiling, almost entirely disappears, apparently from more perfect oxygenation. Muriatic acid does not act on the metal, but oxy-muriatic acid changes it into the blue oxide, and the same oxide is produced by the action of the other acids on the brown oxide. From an excess probably of this oxide, the saline solutions are usually of a blue colour; they can scarcely be obtained crystallized without decomposition.

This blue oxide is, according to Bucholz, soluble in water, reddens litmus paper, and decomposes the alkaline carbonates with effervescence, forming with the alkali a blue solution.

The substance named Molybdic Acid, formed by the preceding processes, is in the state of a yellowish-white powder, having a specific gravity of 3.4. Its taste is sharp and metallic; it is soluble in water, but requires a large quantity for its solution, nearly 1000 parts at 212°; its solution is of a pale yellow colour, has little taste, but reddens infusion of litmus. It is melted by heat, forming a vitreous matter, and if heated strongly, is volatilized. By the action of inflammable and metallic substances, it is reduced to the blue oxide; even the solar light produces this partial de-oxidation, paper immersed in its solution acquiring a rich blue colour from exposure to the rays of the sun, and the action of some of the acids appears to produce a similar change. According to Bucholz, it consists of 77 of the metal with 33 of oxygen.

Molybdic acid combines with the alkalis, and in entering even into these combinations, it appears to suffer a partial decomposition, and to return in part to the state of oxide; the neutral combination with potash does not crystallize; that with soda forms four-sided tables; that with ammonia gives by evaporation a striated yellowish mass.

In its action on the metals, it always suffers decomposition. It may be combined with their oxides by double affinity, and from several metallic salts several compounds of rich colours are thus precipitated by the addition of an alkaline molybdate. The molybdates, added even to the vegetable colouring substances, appear to improve the richness and permanence of their colours.

Molybdena combines with sulphur, forming a substance of a flaky texture, similar to the native sulphuret. With phosphorus it appears to unite, forming a compound not very different in appearance from the metal itself.

Molybdena combines with a number of the metals when exposed with them to an intense heat; but none of its alloys have been applied to any use, nor do they present results sufficiently interesting to require distinct notice.

CHAP. XXIII.

OF TUNGSTEN.

THE name of Tungsten had been given to a mineral, which Scheele discovered consists of what he regarded as a peculiar metallic acid combined with lime. The same metallic matter was afterwards discovered in another more common mineral, wolfram, in which it is combined with manganese and iron. In both these minerals it has since been ascertained, that the tungsten is in the state of an oxide, and that it does not even exist in that of an acid. From the first it is extracted merely by digesting the ore in nitric acid, a yellow powder remaining, which is the oxide of tungsten: to obtain it quite pure, however, it is digested with ammonia, which dissolves it, and it is afterwards precipitated by neutralizing the alkali by nitric acid. From wolfram it is procured by digestion in muriatic acid, which dissolves the iron and manganese; the oxide of tungsten remains; it is combined with ammonia by digestion, and is precipitated by nitric acid; either the precipitate, or the entire matter obtained by evaporation, being calcined with a red heat, by which the adhering nitric acid and ammonia are expelled.

The oxide of tungsten may be reduced to the metallic state, by exposing it moistened with oil in a crucible lined with charcoal to an intense heat. The agglutination of the metal by fusion is, however, extremely difficult. In the state in which it was obtained by Mess. D'Elhuyart, the chemists who discovered its existence in wolfram, it is described as being of a greyish-white colour, with considerable lustre, hard, and brittle; its specific gravity they state at 17.6, which is confirmed by the experiments of Aikin and Allen, while by other chemists it has been stated so low as 8, or even 6.8, probably from imperfect fusion.

Tungsten, though so difficult of fusion, appears to be very susceptible of oxidation, its surface tarnishing when heated under exposure to the air, and a quantity of oxide being formed.

The white powder obtained by the action of nitric acid on tungsten, with subsequent digestion with ammonia and precipitation by nitric acid, Scheele supposed to be a metallic acid. It is soluble in water, requiring not more than 20 parts at 212° for its solution; its taste is acrid, and it reddens the infusion of litmus; it combines too with the alkalis, forming crystallizable neutral salts. From the experiments, however, of Mess. D'Elhuyart, this substance appears to be a ternary compound of oxide of tungsten, nitric acid, and ammonia, which has been confirmed by the experiments of Vauquelin and Hecht. By boiling an acid on it, and afterwards exposing it to a red heat, it is obtained in the state of a yellow powder, which is a pure oxide, and neither possessed of acidity, nor capable of acquiring it. This oxide is insoluble in water, tasteless, and does not change the vegetable colours. By exposure to a strong heat it is partially de-oxidated, and assumes a green colour; and when fused with borax, it forms a globule of a blue tinge, and zinc, iron, or tin, immersed in solutions of its triple salts, with the addition of a little muriatic acid, produces a rich blue colour. It contains about 0.20 of oxygen.

Tungsten is scarcely sensibly acted on by the acids, even nitro-muriatic acid does not dissolve it; nor is its oxide much more soluble. The oxide combines with more facility with the alkalis, especially when a portion of acid is present, and soluble ternary compounds are thus formed.

The combination of tungsten with other metals has been attempted, by exposing to heat mixtures of the different metals with oxide of tungsten and charcoal powder; but these combinations are imperfect, and present no interesting results.

Oxide of tungsten gives permanence to the vegetable colours, and has hence been proposed to be employed in the formation of lakes.

CHAP. XXIV.

OF TITANIUM.

THE oxide of this metal was discovered by Mr Gregor in a ferruginous sand, named Menachanite from being found in the vale of Menachan in Cornwall. Klaproth afterwards discovered the same oxide in the fossil known by the name of red schorl, and it has since been discovered in several other minerals.

The reduction of this oxide is extremely difficult. Vauquelin and Hecht obtained only an imperfectly agglutinated mass, with metallic globules interspersed. Lampadius obtained it more perfectly fused, and found it to be of a copper-red colour with much brilliancy, but liable to tarnish. It appears to be volatile at intense heats. The metal, when heated with the admission of the air, assumes tints of purple and blue from oxidation. In the native oxide, the degree of oxidation appears to be higher, and even it can be oxidated more highly by fusing it with potash, a white precipitate forming when it is dissolved in water, which, according to Vauquelin, contains 0.11 of oxygen.

The acids act very feebly on titanium, and even on the native red oxide. But this oxide, fused with carbonate of potash, being brought to a higher degree of oxidation, and combined with carbonic acid, is more easily dissolved, the carbonic acid being disengaged with effervescence. With sulphuric acid it forms a solution, which on evaporation becomes gelatinous. That in nitric acid affords, by spontaneous evaporation, rhomboidal crystals. The solution in muriatic acid becomes gelatinous when heated, transparent crystals forming in it when cold. Phosphoric and arsénic acids attract the oxide from the other acids, and produce insoluble compounds which are precipitated.

The alkalis decompose the salts of titanium, throwing down white precipitates which are probably sub-salts. The metals immersed in their solutions produce partial de-oxidation, which gives rise to changes of colour.

Titanium does not combine with sulphur; its solutions are not decomposed by sulphuretted hydrogen, but hydrosulphuret of potash throws down a precipitate of a brownish red colour. With phosphorus it forms a compound of a white-colour, brittle and not very fusible.

Its combinations with the other metals remain unknown, that with iron excepted, which is of a grey colour, with metallic particles of a golden colour intermixed.

Oxide of titanium has been used to give a brown colour in porcelain-painting, being applied by the usual flux.

CHAP. XXV.

OF URANIUM.

THIS metal was discovered by Klaproth to form the principal part of the mineral, which had been known by the name of Pechblende, and he afterwards discovered it to exist in the state of oxide, in what had been named green mica, and in another mineral substance which has received the name of uranitic ochre. The reduction of the oxide to the metallic form, he found to be extremely difficult, but by exposing it, formed into a paste with oil or wax, to an intense heat in a charcoal crucible, he obtained a metallic mass. The metal was of a dark grey colour with metallic lustre, and hard with considerable cohesion. Its specific gravity was 8.1.

This metal is extremely infusible, nor does it appear to be very susceptible of oxidation, no change being produced on its surface when it is exposed to the flame of the blow-pipe.

Its oxide is obtained, however, by the action of the nitric or nitro-muriatic acid on its ores, and precipitating the solution by an alkali. It is of a yellow colour, and insoluble in water; when heated to ignition, it becomes of a brownish-grey colour.

The acids in general dissolve this oxide. The solution in diluted sulphuric acid affords by evaporation prismatic crystals of a lemon-yellow colour. That formed by nitric acid affords crystals in the form of six-sided tables transparent, and of a light green colour; that by muriatic acid gives crystals in rhomboidal tables, yellowish-green. The compound with phosphoric acid is sparingly soluble, and does not crystallize.

The alkalis throw down from the salts of uranium, precipitates of a lemon-yellow colour. The precipitates by the alkaline carbonates are white. Prussiate of potash forms a brownish-red precipitate, sulphuret of ammonia one brownish yellow, tincture of galls one of a dark brown. The metals have no effect in decomposing them; a proof of the strong attraction which this metal has to oxygen.

The oxide exposed to heat with sulphur appears to form with it an imperfect combination, which is subverted by a greater elevation of temperature.

Its combinations with the other metals are unknown. Its oxide combines by fusion with vitrifiable substances, and gives to them a brown or green colour.

CHAP. XXVI.

OF TANTALUM.

THE name of Tantalum has been given to a metal extracted from certain minerals found in Sweden, in which it is associated with ittria, manganese, and iron.—The following are its properties.

Its oxide obtained by the processes by which it is extracted, is in the form of a white heavy powder. When exposed to a strong heat with charcoal, it is reduced to a globule having metallic lustre, of a greyish-black colour. The mineral acids reduce this again to the state of white oxide, but in whatever quantity they are added, do not dissolve it, even when boiled on it, or dissolve it only in minute quantity. It is singular, however, that it is dissolved by the vegetable acids, as the oxalic, tartaric, or citric. It is dissolved by the fixed alkalis, and even by the alkaline carbonates, and in larger quantity by potash than by soda. These solutions are decomposed, and the oxide precipitated by an acid. If only as much acid is added as neutralizes the excess of alkali, infusion of galls causes an orange precipitate, but no precipitation is occasioned by prussiate of potash, or by hydro-sulphuret of potash. Infusion of galls poured on the white oxide recently precipitated, and still moist, likewise forms the orange-coloured compound.

A metallic mineral from America had been examined a few years ago by Mr Hatchet, and a substance obtained from it, which he regarded as a distinct metal, and named Columbium. It has lately been found by Dr Wollaston that this is tantalum, the oxide separated from the mineral having all the properties above described.

CHAP. XXVII.

OF CERIUM.

This metal has been extracted from a Swedish mineral which had been regarded as a variety of wolfram, and in which it is associated with oxide of iron, silex, and lime. The oxide of cerium is obtained by dissolving the mineral in nitro-muriatic acid, and after saturating the solution with an alkali, precipitating by adding tartrate of potash: the precipitate well washed, calcined, and digested in vinegar, is oxide of cerium. It is reduced to the metallic state by exposure to an intense heat in mixture with lamp-black, oil, and borax, but in this state it has been obtained only in such a minute quantity, that the properties of the metal have not been described.

The oxide appears to exist in different degrees of oxidation. When precipitated from its solutions in acids by an alkali, it is white; it becomes yellow when dried in the air, and red when exposed to heat. It melts with borax, assuming with it before the flame of the blow-pipe, a blood-red colour, which disappears on cooling.

Cerium Vauquelin found to be insoluble in any unmixed acid, and to be soluble only in minute quantity in nitro-muriatic acid. Its oxide dissolves in sulphuric acid, forming a solution colourless, or of a light-red tinge, of a sweet taste, and which by evaporation affords white crystals; if the oxide is in a high state of oxidation, the solution is of an orange colour, and affords prismatic crystals of the same colour. Nitric acid dissolves the white oxide; the solution has a sweet taste with some sharpness; it does not easily crystallize. The red oxide is dissolved with more difficulty unless heat be applied; the solution is of a yellowish-green colour; when there is an excess of acid, it affords crystals by evaporation, if neutral, it merely becomes thick. Muriatic acid dissolves the red oxide slowly; the solution, evaporated to the consistence of honey, undergoes an irregular crystallization, and affords a deliquescent mass, soluble in water and in alkohol. Phosphoric and carbonic acids form with it insoluble salts.

The salts of cerium are decomposed by the alkalis; precipitates are thrown down, but if an excess of acid be present, triple salts are formed. From the saturated solutions, prussiate of potash throws down a white precipitate; infusion of galls one which is also white; hydro-sulphuret of ammonia, one which is green or brown according to the proportions; and hydro-sulphuret of potash, one which, when iron is not present, is white, and appears to be the pure oxide. Phosphorus throws down a white precipitate; there is no metallic precipitation from the action of iron or zinc.

The alkalis do not act on cerium; ammonia merely renders the oxide yellow without dissolving it; the alkaline carbonates dissolve a small quantity of it, forming ternary salts.

BOOK VII.

OF MINERAL COMPOUNDS.

THE method of classification which I have followed being founded on analogies in chemical constitution and properties, I have in conformity to it placed together, under the above appellation, and as forming a distinct class, substances which in these respects are closely connected. They are those compounds chiefly of earths and metals which occur in nature, forming the principal products of the mineral kingdom.

The characters of these, as objects of chemical science, are rather peculiar. From the nature of their composition, and still more from the state of aggregation, they exert scarcely any important chemical agencies, and display few striking chemical properties; in no case do they enter into chemical combination, and their history is thus in a great measure limited to the description of their physical qualities, and the account of their constitution, so far as this has been discovered by analysis.

From these peculiarities it has happened, that these substances have frequently been regarded as objects of mere description, and hence as belonging to a different department of knowledge from chemistry. It is this which constitutes mineralogy, the object of which strictly is to describe with accuracy the external appearance of minerals, and by these to discriminate them from each other. But still they also fall within the province of chemistry; they are, in common with all natural bodies, objects of its investigations, with the view of discovering their composition; and it is only on this composition that their proper specific distinctions can be established.

It has been attempted, indeed, to establish the species of minerals on other grounds; and in particular it has been assumed, that an agreement in external qualities is sufficient to unite under one species those minerals in which it is observed; and in the system of Werner, this principle frequently regulates the classification, in opposition even to the results of chemical analysis. So far as the properties of bodies are connected with their chemical constitution, an agreement in the former may no doubt be considered as denoting a similarity in the latter; but differences of properties frequently arise from other causes, and in minerals particularly, from the state of aggregation. Hence by attending to such differences alone, substances essentially the same will be regarded as specifically different, and without the light which chemistry reflects, mineralogy would from this cause soon include many inaccurate distinctions.

There is another character connected with the internal structure of minerals, which has been assumed as a basis of their specific distinctions. Hauy, the celebrated French mineralogist, discovered, that in all crystallized minerals, there exists in the crystal a nucleus of a certain geometric form, capable of being extracted from it by mechanical division in those directions which correspond with the natural joinings of the laminæ that compose the entire crystal. This nucleus, or primitive form, as it has been named, he farther found to be the same in the various crystals of one substance, however diversified their figure might be, as, for example, in the different varieties of carbonate of lime; he hence inferred, that it indicated identity of species, and afforded a just ground for the specific distinctions of minerals. Its insufficiency, taken by itself, however, is sufficiently evident from the fact, that the same primitive form is found in substances acknowledged to be totally different; and there is therefore still the necessity of chemical analysis, or of some other principle, to determine its application. The singular fact has farther been established, that in minerals of precisely the same nature, at least as far as the most rigid analysis can determine, the primitive forms of their crystals are in some cases different. And, lastly, the character, were it admitted, is not applicable to those minerals which do not occur in a crystallized state.

The only proper basis of specific distinction in mineral bodies, is chemical composition. It is this which is the source of all their essential properties, and which properly establishes the identity of two substances; and distinctions from other sources are altogether arbitrary and artificial.

In organised bodies, indeed, there is a different ground of specific distinction,—the peculiar organization and form of each individual as a living being, and the power of transmitting these, or of producing a similar being. But in the mineral kingdom this is altogether wanting, and nothing remains equally determinate but the chemical composition.

It is to be acknowledged, however, that the specific composition of these substances is not always easily determined, so as to admit of a method strictly chemical being followed. They usually consist of several principles combined, and diversities of properties are established from differences of proportions frequently minute, and still more from mere differences in the state of aggregation. Ingredients, too, are often contained in them which are not essential to the composition. Our modes of analysis are imperfect, the proportions cannot always be estimated with accuracy, and the modes of combination are in many cases almost unknown. Hence it is often difficult to establish an identity of composition among minerals which have a resemblance in external qualities, or to unite the varieties of a species by the results of their chemical analysis.

From these circumstances it has been found necessary, in fixing the mineral species, to adopt a less rigorous method. A certain combination may be understood to constitute a species, and this can in many cases be unequivocally determined, as in all those cases in which an earth and an acid are united together. There are others in which the composition is more complicated, and in which it is more difficult to determine what constitutes the specific composition, as where the analysis discovers four or five ingredients, united perhaps in different varieties of the fossil in different proportions. In such cases it is necessary to have recourse to other sources of distinction: these are drawn from the external properties of the substances, or from the mechanical structure, as developed in their crystalline forms; and thus many of the species at present received in mineralogical systems, are established as much on these distinctions as on the chemical composition.

It is only to be understood, that these methods are provisional and subordinate. A peculiar composition no doubt constitutes every natural species, and will be discovered in all, as the methods of chemical analysis are improved.

The classification of minerals is thus to be regarded as essentially chemical. Each earth, for example, or each metal, forms a genus, under which are arranged as species the particular fossils in which it predominates; the native saline compounds, as well as the mineral inflammables, are arranged on a similar principle. And under all these genera the species are established, as far as the imperfect state of the science admits, on identity of composition.

It is obvious, that in thus considering the description of minerals as subservient to their chemical relations, those minute details of external qualities and appearances which properly belong to a strictly mineralogical work are in a great measure excluded. It is sufficient to enumerate the more important and characteristic properties, those which unite the varieties of the species, and serve to distinguish it from others. It is in conformity to this principle, that

I have given the brief mineralogical descriptions in the following chapters. It is equally evident, that in conformity to these views, a place can be given to those minerals only which have been fully examined, and are well defined.

The properties of minerals being often diversified by slight shades of differences, and such differences being at the same time frequently of importance in affording characters of distinction, it has become necessary to employ mineralogical language with much precision; and hence all the terms employed to denote the external appearances of minerals have been exactly defined. Such a view of this language as is consistent with the limits of this treatise, would scarcely be of any utility; and the subject being scarcely elementary, I refer for an abstract of it to my larger System, or to the treatise by Professor Jameson on the External Characters of Minerals.

CHAP. I.

OF SALINE MINERALS.

UNDER this order have been frequently placed all those mineral substances which have the general characters of salts,—are sapid, soluble in water, and crystallizable. Several of these, however, have a metallic or earthy base, and according to the principles of chemical arrangement, may be placed under the genus of earthy or metallic fossils, with which they are connected. There will thus remain included under the order, only those few compounds formed from the combinations of acids with alkaline base. These may be arranged according to their base.

SECT. I.—*Of Native Salts with Base of Ammonia.*

MURIATE of ammonia is the only species which can be referred to this genus. It is sometimes found as a product of volcanoes, or predo-volcanoes, being probably formed by the action of heat on substances containing its elements, and sublimed, in the form of an efflorescence, loose and flaky; sometimes also massive, tuberose, or even indistinctly crystallized; and is easily recognised by its chemical properties.

SECT. II.—*Of Native Salts with Base of Potash.*

NITRE or nitrate of potash, is the only species belonging to this genus. It occurs as an efflorescence on the surface of the ground in warm and dry climates, on soils strongly impregnated with vegetable and animal substances, and is evidently formed, as has been already remarked, from the elements evolved in the decomposition of these substances. It sometimes too forms an efflorescence on limestone rocks; it is easily distinguished by its cool taste, and by the deflagration it excites in burning fuel.

SECT. III.—*Of Native Salts with Base of Soda.*

Four salts are comprised under this genus,—sulphate of soda, carbonate of soda, muriate of soda, and borax.

Sulphate of soda is a frequent ingredient in mineral springs; it is sometimes deposited at the sides of salt lakes, or as an efflorescence on the soil in their neighbourhood, and is easily discovered by its chemical characters.

Carbonate of soda is found native in the form of an efflorescence on the surface of the ground in different countries, particularly in India: in some of the interior districts in Africa, it occurs in crystalline layers or deposites. And in Egypt and Hungary, it is found dissolved in the water of certain lakes, from which, in the dry season, it is likewise deposited. In all these cases it is found associated with sulphate and muriate of soda; and from the description given by the French chemists of the lakes in Egypt and the nature of the surrounding rocks and soil, it appears to be derived from the infiltration of water, holding muriate and sulphate of soda dissolved, through a bed of carbonate of lime, the muriatic and sulphuric acids being probably abstracted by the lime, and the carbonate of soda removed by efflorescence, so that the re-action of the muriate of lime on it is obviated.

Muriate of soda, the Rock-salt of mineralogists, is the most abundant saline product of the mineral kingdom, being found in immense deposites, besides what exists in mineral springs, and in the water of the ocean. It is in masses, having a crystalline structure, transparent, or semi-transparent, of a white-grey or reddish colour, with vitreous lustre, and having a taste purely saline. Its fracture is foliated, sometimes fibrous, and its fragments are cubical. It is usually pure, or contains only a minute quantity of iron. Its beds are connected with rocks of secondary formation.

Borax or sub-borate of soda, it has already been stated, is found in Thibet, being deposited from the water of a lake in which it is dissolved, in crystalline masses, sometimes of regular forms, of a greenish colour, and semitransparent, with vitreous lustre, having a foliated fracture. There appears to be a constant reproduction of it, as, although it has been long dug, there is no appearance of it being exhausted; but of its origin nothing is known.

CHAP. II.

OF EARTHY MINERALS.

Under this order are placed those fossils in which the primary earths are the predominating ingredients, though with these are frequently combined saline and metallic substances. It is subdivided into genera, according to the particular earth which enters principally into the composition; and under each genus the species containing this earth are arranged. Generally speaking, the earthy fossils are tasteless, insoluble in water, uninflammable, and of moderate specific gravity.

SECT. I.—*Of Barytic Minerals.*

UNDER this genus there are only two species, the Sulphate and the Carbonate. They are distinguished from other earthy fossils, by their greater specific gravity.

SULPHATE OF BARYTES.—The Heavy Spar of mineralogists forms several sub-species. The common variety, the Lamellar, or Foliated, occurs massive, and often crystallized: the forms of its crystals are numerous, but are all reduced to the oblique four-sided prism, and the rectangular four-sided table, either perfect, or modified by truncation or bevelment of the edges or angles. The colour is white, frequently with shades of grey, yellow, brown, or red; the lustre shining, intermediate between pearly and vitreous: it is transparent, semi-transparent, and, when massive, often only translucent: its fracture is foliated, straight or curved. It is moderately hard; is brittle and heavy, its specific gravity being from 4.3 to 4.5. It melts before the blowpipe into a white enamel. It consists of sulphuric acid and barytes, with, in several varieties of it, small proportions of sulphate of strontites, silex, argil, and iron.

The other varieties are so unimportant, as scarcely to require distinct notice. Granular Heavy Spar presents a fracture very small, and fine foliated, and contains about 10 of silex in 100 parts. Compact Heavy Spar has a fracture fine grained uneven, passing into coarse earthy; has less lustre; is opaque, or only translucent on the edges; is massive, sometimes earthy and dull. Columnar Heavy

Spar derives its name from the appearance of its crystallized masses, which are composed of oblique four-sided prisms, aggregated in a columnar form. The Bolognian Heavy Spar occurs in rounded masses, and presents a radiated fracture; the rays, or narrow planes, being parallel or divergent.

CARBONATE OF BARYTES occurs massive, in globular pieces, and rarely crystallized. Its crystals are six-sided prisms, acuminated by six planes and double six-sided pyramids; its colour is white, with a shade of grey; it is translucent or semi-transparent; its lustre is shining. Its fracture, in one direction, is intermediate between radiated and foliated, in another uneven; its fragments are wedge-shaped; it is semi-hard; its specific gravity is 4.3. It is fused by the flame of the blowpipe into a white enamel; dissolves with effervescence in diluted nitric acid. According to Withering, it consists of barytes 78.6, carbonic acid 20.8. Klaproth found it in a small quantity of carbonate of strontites, with minute traces of argil, oxide of copper, and oxide of iron.

SECT. II.—*Of Strontitic Fossils.*

THE natural species of this genus are those in which the earth is mineralized by sulphuric and by carbonic acids. The SULPHATE occurs massive, and crystallized in six-sided tables, or in rhomboidal four-sided prisms acuminated by four planes. Its colour is milk-white, frequently with a shade of blue; sometimes it is of a grey colour, or of a reddish tinge. The crystals are semi-transparent, or translucent: the massive is nearly opaque: its lustre, when crystallized, is shining; when massive, it is dull. The fracture is foliated, fibrous, or compact fine splintery. The specific gravity is from 3.5 to 3.8. It consists of strontites 58.25, sulphuric acid 41.75, with a little oxide of iron; and in some varieties, 8 or 10 parts of carbonate of lime.

The Carbonate has been found only at Strontian in Argyleshire. It is usually massive: sometimes from the mass slender crystals shoot, which appear to be six-sided prisms acuminated by six planes. Its colour is light green: frequently it is only of a greenish white, sometimes of a yellowish colour; its lustre is shining and pearly: its fracture is fibrous or radiated; it is semi-hard, brittle; has a specific gravity of 3.6 or 3.7. Before the flame of the blowpipe it becomes white and opaque, but is not fused. It dissolves in diluted nitric acid with effervescence. According to Dr Hope's analysis of it, it consists of strontites 61.21, carbonic acid 30.2, water 8.59.

Sect. III.—*Of Calcareous Fossils.*

The fossils which belong to this genus consist of lime, in combination with different acids.

Sulphate of Lime forms the Gypsum of mineralogists. Four varieties have been formed,—the Earthy, Compact, Fibrous, and Foliated. The first occurs pulverulent, or slightly indurated; of a yellowish or greyish-white colour; dull and meagre to the touch. Compact Gypsum is the substance named Alabaster, which is used for statuary. It is massive; its fracture is even; its colours are usually shades of grey: it has little lustre, though it acquires it when polished: it is translucent on the edges, and very soft. Fibrous Gypsum occurs massive: its fracture is distinctly fibrous, more or less broad; the fibres being straight or curved, and always parallel: its usual colour is white, frequently with shades of grey, yellow, or red: its lustre is shining and silky: it is translucent, or semi-transparent; is so soft as to be scratched by the nail: its specific gravity is 2.3. The last variety, the Foliated Gypsum, including the Selenite, occurs massive and crystallized; the forms of its crystals being the oblique six-sided prism bevelled, or acuminated by four convex planes at each extremity; and when the prism is wanting, these planes united form a spherical convex lens. Its colours are generally white: its lustre, when crystallized, is shining, generally pearly: when massive, it is more dull: it is, when crystallized, transparent; when amorphous, it varies from this to translucent: its fracture is curved foliated; sometimes diverging radiated: that of what has been named Selenite is large foliated, or straight, sometimes curved: it is easily split: it is soft, so as to be scratched by the nail; feels smooth; has a specific gravity of 2.3.

All the varieties of native sulphate of lime have nearly the same chemical characters. They lose their transparency before the flame of the blowpipe; and when strongly urged by the flame, give a white or yellowish enamel. They are soluble in sulphuric acid, when its action is aided by heat. Selenite, which is the purest variety, consists of lime 32, sulphuric acid 46, water 22: the several varieties frequently also contain carbonate of lime, oxide of iron, argil, and silex.

A native sulphate of lime has been discovered, into the composition of which water does not appear to enter, and which perhaps forms therefore a distinct species. It has been named the Anhydrous Gypsum, and differs from the other in its forms of crystallization, and in being harder. According to Mr Chenevix's analysis of it, it consists of 44.88 of acid, and 55.12 of lime. The Anhydrite, and the Cube Spar of Werner, have both been described as anhydrous sulphate of lime.

Carbonate of Lime occurs in very different states, arising from differences in its aggregation, and from the intermixture of other substances besides its immediate principles. There is hence considerable difficulty in arranging its varieties, and in determining whether some of them ought not to be regarded as distinct species.

Crystallized Carbonate of Lime.—The Calcareous Spar of mineralogists is the species in its purest state. The primary forms of its crystals are the six-sided pyramid, the three-sided pyramid, and the six-sided prism; with numerous modifications from combination, acumination, bevelment, and truncation, giving rise to a variety of other forms: the crystals are generally transparent, or semi-transparent: they have very distinctly the property of double refraction; the lustre is usually shining and resplendent, vitreous, or sometimes pearly: the colour is white, sometimes also grey, green, red, yellow, and light purple. The fracture is foliated, with a threefold cleavage: the fragments are rhomboidal: it is semi-hard, so as to be easily scratched with a knife: it is also brittle: its specific gravity is 2.7. It decrepitates before the flame of the blowpipe, but does not melt: it effervesces strongly with the acids, and is entirely soluble in diluted nitric or muriatic acid. According to its analysis by Vauquelin, it consists of 56 of lime, with 43.5 of carbonic acid.

There are some crystallized fossils, which, from the most accurate chemical analysis, can be discovered to consist only of carbonate of lime, yet which differ from calcareous spar in some of the most essential characters. Arragon Spar, or Arragonite, is the fossil with regard to which this was first observed. Haüy found that the cleavage was different, indicating a different crystalline arrangement, and a difference in the forms of their primitive molecules; and it differs also in hardness and specific gravity. It still continues, therefore, to afford the greatest difficulty in the crystallographic system of Haüy, and presents undoubtedly a singular anomaly. The hard carbonate of lime described by Bournon, and which exhibits a similar anomaly, is probably to be placed with the arragonite. Its specific gravity is nearly the same, being 2.912: its hardness is equally superior to that of calcareous spar, and exceeds a little that of the arragonite itself: and there appears to be some difference in its crystalline structure; no difference can be discovered in the composition between it and common carbonate of lime.

Fibrous Carbonate of Lime.—This variety occurs massive, or in various imitative shapes; the stalactites and stalagmites, which are deposited from water, holding carbonate of lime in solution, belong to it; but it also occurs, not of stalactitic origin, in veins. Stalactitic carbonate of lime is, from the nature of its formation, presented under various external shapes, conical, tuberose, coraliform, and botryoidal. Its colour is white, frequently with shades of grey, yellow, red, and green: its lustre is usually weakly shining; it is translucent, approaching to semi-transparent; its fracture is fibrous, the fibres being straight, and generally divergent; it is rather softer than the calcareous spar: its specific gravity is 2.7. Its chemical characters are the same with those of the other varieties of carbonate of lime. The Pisolithe, or Peastone, so named from the mass being composed of small rounded concretions like peas, appears to be of a similar origin. Roestone is probably connected with this. It is in small globular concretions, dull, opaque, of a brown or yellowish colour, soft, and easily broken.

Granular Carbonate of Lime, or Granular Limestone, occurs massive, forming extensive strata, generally connected with primitive rocks, or those of transition, and hence sometimes receiving the name of Primitive Limestone. Its fracture is small foliated, sometimes splintery; its colours are white and grey; its lustre varies from shining to glimmering, and is intermediate between pearly and vitreous;

it is translucent; is harder than calcareous spar, and less brittle. Its specific gravity is 2.7 or 2.8. It effervesces with acids. Its analysis has been extended to few of its varieties. It appears often to be a carbonate of lime nearly pure, but it sometimes also contains silex, argil, and magnesia, in proportions variable, and not well determined.

The granular limestone furnishes some of the finest marbles, and particularly those which are used for statuary.

COMPACT CARBONATE OF LIME, or Compact Limestone, is carbonate of lime much less pure, other substances being generally present in considerable proportion. Its fracture is always compact, generally small scaly, passing into uneven or earthy. Its usual colour is grey, but frequently diversified with shades of other colours: it is dull, and a little translucid on the edges; it is semi-hard; has a specific gravity of 2.6 or 2.7. It occurs always massive, generally regularly stratified, and in connection with other secondary strata, and often contains in great abundance the remains and impressions of organic beings, particularly of marine animals. It is in common use for burning into lime, and when of a fine grain, is sometimes polished as marble.

Chalk is a carbonate of lime nearly pure, deriving its external characters from its state of aggregation. It occurs massive, generally in beds; is little indurated: its fracture is earthy; its colour white, or yellowish, dull, and opaque; is so soft as to soil. It dissolves in acids with effervescence.

Marl is an impure carbonate in a loose state of aggregation. It is sometimes composed of earthy particles, is dull, and feels meagre: sometimes it is more indurated, but is still so soft as to yield to the nail; it effervesces with acids, and generally falls to powder in water, or under exposure to atmospheric air. Marls contain, besides carbonate of lime, generally clay, magnesia, silex, and oxide of iron, in variable quantities. The medium proportion of carbonate of lime is from 50 to 60 *per cent.*

There remain some fossils, in which carbonate of lime is chemically combined with other principles, and which perhaps properly constitute distinct species.

Pearl Spar, or Brown Spar, is carbonate of lime, with oxides of iron and manganese: it occurs massive, disseminated, and crystallized; its crystals being rhombs, or lenses: its colours are white, often with shades of grey, yellow, or red; but, from exposure to the air, its colour darkens, and becomes brown. Its lustre is shining and pearly; it is semi-transparent or translucent; its fracture is usually curved foliated; its fragments are rhomboidal; its hardness and specific gravity are a little greater than those of calcareous spar: it blackens before the blowpipe; it effervesces with acids, but not strongly. It usually contains above 50 of carbonate of lime, with variable quantities of iron and manganese. When these are in large proportion, it forms the Sparry Iron Ore. The manganese appears to exist in it at the minimum of oxidizement; and it is from it absorbing oxygen, that the deepening of the colour from exposure to the atmosphere happens.

Rhomb Spar, or Bitter Spar, consists of carbonate of lime with carbonate of magnesia, and a little oxide of iron and oxide of manganese. It occurs crystallized in rhombs, which are semi-transparent, or translucent; has a shining lustre, and is of a white or grey colour. Its fracture is straight foliated; its fragments are rhomboidal; it is rather harder than calcareous spar; its specific gravity is less, being only 2.48. It effervesces little with acids.

Schieffer Spar, or Argentine, occurs massive; has a high pearly lustre; is translucent, and of a white colour, with shades of green or red; its fracture is curved foliated; its fragments are slaty, or wedge-shaped; is soft; its specific gravity is 2.7: it effervesces strongly with acids. Heated, it becomes brown, and may be fused into a brown porcelain. Its composition, according to Mr Aikin's analysis, is carbonate of lime 98.118, silex 0.5, oxide of iron .8, with 1.032 of loss. It appears to pass into what has been named Silvery Chalk, or Schaum Earth, which has the same pearly lustre and colours, but occurs in a state of less induration. Schaalstone appears to be similar; it occurs massive, is of a white colour, with shades of green, red, or yellow, and a lustre shining and pearly.

Fœtid Carbonate of Lime, or Swinestone, according to Vauquelin, is a carbonate of lime impregnated with sulphuretted hydrogen, from which it derives an unpleasant odour, especially perceptible when rubbed. It occurs massive; its colour is brown, with little lustre; its fracture is earthy, or scaly. When heated, it loses its colour and smell, and is converted into lime.

Phosphate of Lime occurs under different forms, which can be connected only by chemical characters.

What has been named Phosphorite is found massive in extensive beds in an earthy or little indurated state. Its colour is yellowish or greyish white, without lustre or transparency, rough to the touch, and having a specific gravity of 2.8. It is highly phosphorescent when heated or rubbed. Pelletier found it to consist of lime 59, phosphoric acid 34, fluoric acid 2.5, silex 2, iron 1.

Apatite is another variety of phosphate of lime. It occurs generally crystallized; the form of its crystals being the equiangular six-sided prism; the colours are white, green, blue, and red, of various shades, generally pale; the external lustre resplendent, with a transparency more or less perfect; the fracture is imperfectly foliated; the hardness such as to be easily scratched by the knife; the specific gravity is 3.2. When thrown on burning fuel, it gives a greenish phosphoric light. It consists of 55 of lime and 45 of phosphoric acid.

There is still a third variety of phosphate of lime, very different in its external characters. From its lustre and transparency, it had been ranked as a gem, being regarded as a variety of the chrysolite. On analysing it, Vauquelin was surprised to find it composed of phosphoric acid and lime; and the proportions are the same as in the apatite. It occurs crystallized, its crystals being equiangular six-sided prisms, acuminated by six planes. Its colour is asparagus green, whence it has received the name of Asparagus or Spargel Stone: its lustre is shining or resplendent, and resinous; it varies from translucent to nearly transparent: its fracture is foliated: it is semi-hard, brittle, and has a specific gravity of 3. It is soluble in nitric acid, and in diluted muriatic acid; but is not, like the other varieties of this species, phosphorescent.

Fluate of Lime, or Fluor Spar, a fossil, distinguished very generally by the beauty of its colours, is found massive, and frequently also crystallized; the forms of its crystals are the cube, perfect, or modified by truncation of the angles or edges, bevelment of the edges, and acumination of the angles by three or by six planes. Its colours are numerous, principally shades of purple, yellow, green, blue, red, and grey, and often intermixed: the lustre is resplendent or shining, and is vitreous: the transparency varies from perfectly transparent to translucent: the fracture is foliated; it is scratched by the knife, but it scratches calcareous spar: it is brittle: its specific gravity is 3.2. Exposed to the flame of the blowpipe, it decrepitates, and then melts into an enamel: on burning fuel, or on a red hot iron, it gives a beautiful purple light, and is also phosphorescent from friction. Its composition, as established by Scheele's experiments, is lime 57, fluoric acid 16, water 27.

The variety named Compact Fluor is distinguished principally by its fracture; it is always massive, has less lustre than the foliated, and is only translucent.

SECT. IV.—*Of Magnesian Fossils.*

UNDER this genus are comprehended those fossils in which magnesia is the ingredient present in largest proportion, and also those in which, though in smaller proportion, the characters peculiar to it exist, those in particular of softness and apparent unctuosity.

What has been named Native Magnesia, appears to be a carbonate, consisting of magnesia and carbonic acid, in nearly equal parts. It occurs in tuberose pieces, of a yellowish-grey colour, without lustre or transparency: it is soft, feels meagre, and adheres a little to the tongue. The substance named Meerschaum, consists of magnesia united with silex, a portion of carbonic acid, and a trace of lime. Its colour is yellowish-white, without any lustre; its fracture is earthy; it is soft, feels a little greasy, and adheres to the tongue. It is not melted by the heat of the blowpipe; nor does it effervesce with acids.

Steatite, named also Soap Rock, from its softness, and feeling soapy, occurs massive. Its colour is greyish, greenish, or reddish-white; it has little lustre; is translucent on the edges: its fracture is uneven, or coarse scaly: it is soft, or very soft; feels unctuous—does not adhere to the tongue: its specific gravity is 2.6. It does not melt before the blowpipe, but becomes white and very hard. The proportions of its constituent parts vary. One variety from Cornwall, analysed by Klaproth, gave silex 48, magnesia 20.5, argil 14, oxide of iron 1, water 15.5.

There are some fossils similar to steatite in external properties, and which have been considered as allied to it, which, it is singular, contain no magnesia. Such is the Plastic Stone, or Figure Stone of China; the Bildstein or Axestone of the Germans, and the Oriental Jade. All these are composed principally of silex, with argil or lime.

Potstone is allied to steatite. It occurs massive; is grey, passing into green, or sometimes with a shade of red. It is dull, and is opaque or translucent on the edges.

Its fracture is curved foliated, or imperfectly slaty: it is soft; feels unctuous: its specific gravity is 2.8. It is infusible before the blowpipe, and hardens in the fire.

Serpentine derives its name from the variegated disposition of its colours. The principal colour is green, but with this are intermixed, in stripes or specks, other colours, particularly red. It has no lustre, though it acquires it when polished; it is also without transparency. Its fracture is splintery: its hardness such that it is easily scratched by the knife: its specific gravity is 2.6. It feels soft, but with little unctuosity. It always occurs massive, and forms entire rocks. It consists of silex and magnesia, with a portion of iron, and sometimes of argil.

Schillerstone is regarded by Werner as allied to serpentine, in which it is often imbedded. Its colour is green, generally dark, with sometimes a shade of yellow: its lustre is shining and semi-metallic, and varies according to the position with regard to incident light; it is translucid on the edges: its fracture is foliated; it is soft, and a little unctuous; its specific gravity is 2.8. It consists of silex 41, magnesia 29, argil 3, lime 1, oxide of iron 14, and 10 of water.

Chlorite.—Of this fossil there are several varieties, differing principally in the state of aggregation. Common Chlorite occurs massive and disseminated. Its colour is dark-green; its lustre is weakly shining, and somewhat greasy; and it is opaque. Its fracture is earthy or fine foliated; it feels meagre, or very slightly unctuous. Foliated Chlorite, so named from its fracture, which is curved foliated, occurs massive and disseminated, and also crystallized in six-sided tables; its colour is dark-green, its lustre shining and pearly, inclining to resinous; it is translucent on the edges; is soft, and feels rather unctuous. Chlorite Slate, distinguished by its slaty fracture, forms a mountain-rock; its colour is dark-green; its internal lustre is weakly shining, and resinous: it is opaque, is soft, and feels unctuous. Earthy Chlorite is composed of small scaly particles, or is quite loose, with little lustre, of a dark-green colour; feels rather greasy; and when breathed on, gives an earthy smell. All these consist of magnesia and silex, with oxide of iron, and small proportions of argil and lime.

Talc occurs massive, disseminated, and in small tabular crystals, confusedly grouped. Its colour is greenish, or yellowish white; its lustre is resplendent; it is translucent, or transparent in thin leaves; its fracture is straight and curved foliated; the plates into which it is divisible are flexible, but not elastic; it is unctuous to the touch. It is infusible before the blowpipe, but is melted in the heat excited by oxygen gas. It consists, according to its analysis by Hœpfner, of silex 50, magnesia 44, and argil 6. Indurated Talc occurs massive; its fracture is slaty; it is less soft and greasy than the common talc, and has less lustre. Earthy Talc is in small scales, of a pearly lustre, friable, soiling a little, and feeling rather unctuous.

Asbestos.—To this species belong several varieties. Common Asbestos occurs massive; its colour is green or grey; its lustre is weakly shining; it is translucid on the edges; its fracture is fibrous or radiated, the fibres being straight or curved; it is soft, or semi-hard, and its fibres are rigid; it feels a little unctuous. It melts, though with difficulty, before the blowpipe. Silex, magnesia, and iron, appear to be the essential ingredients.

Amianth is a variety of the same species, distinguished by its texture, being more delicately fibrous, so that the fibres are easily separated, are fine and perfectly flexible. It has more lustre also, this being pearly or silky; it is faintly translucent; its colour is lighter, and sometimes it is nearly silvery-white. In composition, it appears to differ from asbestos in containing more silex. It is this substance which was employed by the ancients to form an incombustible cloth to collect the ashes of the dead on the funeral pile.

Mountain Cork is another variety, so named from its resemblance to a piece of cork. It is in flat pieces, of a grey colour, without lustre, and opaque; its fracture is fibrous; the fibres being short, and interwoven; is a little flexible; it feels meagre, and is so light as to float on water. When its texture is more close, and it occurs in thinner pieces, it is named Mountain Leather.

Actynolite.—Of this species there are three varieties, —the asbestous, the common, and the glassy actynolite. Asbestous actynolite occurs massive, or more rarely in capillary crystals. Its fracture is fibrous or radiated; its colour is greenish-grey; its lustre is shining, and silky; it is opaque and soft; its specific gravity is from 2.5 to 2.9. It melts before the blowpipe. Common Actynolite occurs massive and crystallized; its crystals being rhomboidal six-sided prisms frequently acicular, and generally imbedded; its colour is green, usually dark; the external lustre is resplendent and vitreous: its crystals are transparent, or semi-transparent: it is sufficiently hard to scratch glass; and is brittle. It is composed of silex 64, magnesia 20, argil 2.7, lime 9.3, iron 4. GLASSY ACTYNOLITE occurs massive, or in aggregated acicular crystals: its colour is green, passing into greenish white: its lustre is shining and vitreous: it is translucent: its fracture is fibrous or radiated: it is brittle, and moderately hard: it melts at a high heat into a glass. Granular Actynolite is of a grass-green colour; is slightly translucent; internally shining; its fracture is foliated.

TREMOLITE, like the preceding species, comprehends three varieties,—the Asbestous, the Common, and the Glassy Tremolite. The first occurs massive, or in acicular crystals; its colour is white; its lustre is weakly shining, and silky; and it is translucent on the edges: its fracture is fibrous; it is very soft, and brittle. The common tremolite occurs massive, or crystallized in oblique four-sided prisms, bevelled or truncated on the lateral edges, and promiscuously aggregated. Its colours are greenish, greyish, reddish, or yellowish white: its lustre is shining and pearly: it is translucent, or semi-transparent: its fracture is radiated: it is hard so as to scratch glass; is brittle, and somewhat meagre to the touch. The Glassy Tremolite occurs massive, or crystallized in slender prisms aggregated: its colours are the same as those of the others; its lustre is vitreous, passing to pearly; it is translucent; its fracture is radiated, or fibrous: it is semi-hard, brittle, and harsh to the touch. All these varieties are often possessed of the property of phosphorescence, so that a moderate heat, or the slightest friction, produces a luminous appearance. A variety of this species, analyzed by Klaproth, gave silex 65, magnesia 10.33, lime 18, oxide of iron 0.16, water and carbonic acid 6.5.

SECT. V.—*Of Argillaceous Fossils.*

THE Argillaceous Fossils afford a striking example of the deficiency of the external characters in uniting the different species which belong to one genus; the gems distinguished by their transparency, lustre, and hardness, being comprised under this genus, equally with the dull and plastic clays. They are connected entirely by their chemical relations.

The gems had been placed among the siliceous fossils, as allied with several of them in external characters, and silex had been supposed to be their principal ingredient. Bergman first shewed the error of this opinion, and proved by analysis, that in the emerald, sapphire, topaz, ruby, and hyacinth, argil predominates. The specific characters of these fossils had also been much perplexed by the distinctions of the jewellers, founded merely on those qualities which give them mercantile value, and particularly on colour, the most variable of all the external characters; and it has required much mineralogical discussion to remove the obscurity, and establish the proper species. It now appears that the principal gems which have been distinguished by the epithet of Oriental, the ruby, sapphire, and topaz, are mere varieties of one species. They have been ranked as such by Werner under the name of Sapphire, and by Haüy under that of Télésie; and more lately Bournon has shewn that they are allied to the fossil named Corundum, and has distinguished the species by the name of Perfect Corundum. This arrangement has been confirmed by chemical analysis, the experiments of Klaproth, Vauquelin, and Chenevix, having proved that all of them consist of argil nearly pure.

PERFECT CORUNDUM, the Sapphire of Werner, occurs in fragments, and crystallized; the forms of its crystals being the double three-sided pyramid, the single six-sided pyramid, and the six-sided prism, variously modified by truncations and acuminations. Its colours are blue, green, red, yellow, and yellowish-white, of numerous shades. It is transparent: its lustre is resplendent and vitreous: the fracture is conchoidal, or imperfectly foliated: the hardness inferior to that of the diamond, but superior to that of every other fossil, and not yielding to the file: the specific gravity is from 3.9 to 4.1. The distinctions from colour form the different oriental gems. The red constitutes the oriental ruby; the blue, the sapphire; the yellow, the topaz; the purple, the amethyst; the green, the emerald; the yellowish-green, the chrysolite. It is only to be remarked, that there are gems to which several of these names belong, distinguished by the epithet Occidental, which are altogether different.

These fossils are not fusible by the blowpipe, but are melted by the heat excited by oxygen gas directed on burning charcoal. They are generally phosphorescent from friction.

The variety of a blue colour, the Oriental sapphire, analysed by Klaproth, was found to be composed of 98.5 of argil, 1 of oxide of iron, and 0.5 of lime: it is argil, therefore, nearly pure. The ruby afforded to Chenevix, 90 of argil, 7 of silex, and 1.2 of iron.

Imperfect Corundum, or, as it is generally named, simply Corundum, is a fossil which has been long used in India, from its great hardness for polishing hard stones. It occurs massive, disseminated, and crystallized; the forms of its crystals being the same as those of the perfect corundum. Its colour is greenish-white; externally it is dull, internally shining and vitreous: the fracture is foliated; the fragments rhomboidal: it is very hard, but rather less so than the perfect corundum: its specific gravity is 3.7 or 3.8. From the aggregation of this fossil, it is scarcely acted on by any chemical agent, and from this Klaproth at one time supposed it to be composed of a new earth; subsequent investigation proved that it consists chiefly of argil, the proportions being from 84 to 90, with 5 of silex, and from 1 to 7 of oxide of iron.

The fossil substance known by the name Emery is of the same family. It occurs only massive, or disseminated: is of a grey colour, dull and opaque. Its fracture is fine grained uneven: it is nearly as hard as corundum, and is used for the same purposes, and particularly for polishing the metals. Analysed by Mr Tennant, it was found to be composed of 86.5 of argil, 3 of silex, and 4 of iron.

To a species, distinguished by the name of Spinelle, are referred the gems known by the names of Spinell and Balass Rubies. It occurs in grains, and crystallized; the form of its crystals being the octaedron. Its colour is red, a deep crimson-red forming the spinell ruby; a pale rose-red the balass ruby: its lustre is resplendent and vitreous: it varies from translucid to transparent: its fracture is conchoidal, or foliated: it is very hard: its specific gravity is from 3.5 to 3.7. According to Klaproth, it consists of 74.5 of argil, 15.5 of silex, 3.25 of magnesia, 1.5 oxide of iron, and 0.75 lime; Vauquelin found it to contain chrome.

The Occidental Topaz, which is found principally in Saxony, Siberia, and Brazil, deviates still more in composition from the corundum. It occurs massive, or in fragments, more frequently crystallized: the form of its crystals being the oblique tetraedral prism, variously modified. Its principal colour is yellow: its lustre is resplendent and vitreous: it varies from transparent to translucent: its cross fracture is foliated: it is very hard: its specific gravity is 3.5. The Saxon topaz was found by Vauquelin to consist of 68 of argil, 31 of silex; but, by a subsequent analysis, he discovered fluoric acid in it, as well as in the Brazilian topaz.

Chrysoberyl is a species allied to these. It occurs in grains, and crystallized under the forms of the six-sided table, and the double six sided pyramid. Its colour is pale-green, often exhibiting a milk-white opalescence: its internal lustre is resplendent: it is semi-transparent: its fracture is conchoidal: it is so hard as to scratch glass: its specific gravity is 3. 7. Klaproth found it to be composed of argil 71.5, silex 18, lime 6, oxide of iron 1.5, with 3 of loss.

Cyanite has been placed under the magnesian genus, but it rather belongs to the argillaceous. It occurs massive, disseminated, and crystallized; the crystals being oblique, flat, tetraedral prisms, truncated on the lateral edges. Its principal colour is blue; but it also occurs white and grey: its lustre is shining and pearly: it is translucent, or transparent. Its fracture is radiated, or foliated: it is semi-hard: its specific gravity is 3.5. It consists of argil 55, silex 29.2, lime 2.25, magnesia 2, oxide of iron 6.65.

Lepidolite occurs massive: the mass is of a purple colour, but presents silvery white scales, of a pearly lustre: it is translucid on the edges: its fracture is small grained uneven; it is soft; its specific gravity is 2.8. It melts before the blowpipe, with intumescence, into a white pearly-like matter. Klaproth found it to be composed of silex 54.5, argil 38.25, oxide of manganese and iron 0.75, potash 4.

Mica is an important fossil, from its extensive distribution, as an ingredient in several of the aggregate rocks. It occurs disseminated, in thin plates, and sometimes crystallized; the crystals being six-sided tables, and six-sided prisms; its usual colour is grey; the lustre of its plates is resplendent, and metallic; in thin plates it is transparent; its fracture is distinctly foliated; and it is very easily split into laminæ, which are flexible and elastic; it is soft, and feels smooth, but not unctuous; its specific gravity is from 2.7 to 2.9. According to Vauquelin's analysis, it consists of silex 50, argil 35, oxide of iron 7, lime 1.33, magnesia 1.35, with 5.32 of loss.

Hornblende occurs massive, disseminated, and sometimes crystallized; its crystals being prisms, usually aggregated. Its colour is black, with frequently a tinge of green; its internal lustre is shining; when of a black colour, it is opaque; when green, translucent on the edges. Its fracture is foliated, or broad radiated; its hardness such that it is scratched by the knife; but it cannot be broken but with difficulty. Its specific gravity is from 3.6 to 3.8. Before the blowpipe, it melts into a greyish-black glass. Its analyses have presented different results, but silex, argil, and oxide of iron, are the chief constituents. Labradore Hornblende is merely a variety, distinguished principally by its copper-red colour. Basaltic Hornblende occurs imbedded in crystals, usually small, of the form of the six-sided prism; their colour is black; their surface smooth; their internal lustre splendent. Hornblende Slate is distinguished by its slaty fracture; it occurs always massive, and often in large beds.

Basalt forms an extensive mountain-rock, assuming often a columnar form. Its colour is greyish-black; it is nearly without lustre; is opaque, or feebly translucent on the edges; its fracture is usually uneven; it is hard, so as to be scratched by the knife with some difficulty, and it is not easily frangible; its specific gravity is from 2.8 to 3. It melts easily before the blowpipe into an opaque black glass; and has been from this quality employed in the manufacture of the coarser kinds of glass. According to its analysis by Dr Kennedy, it is composed of silex 48, argil 16, oxide of iron 16, lime 9, soda 4, muriatic acid 1, water and other volatile matter 5.

CLINKSTONE has received its name from the peculiar sound it gives when struck. It occurs always massive, and forms beds, and sometimes assumes the columnar form; its colour is grey; it is dull, or weakly shining, and translucent on the edges. Its fracture is slaty; it is semi-hard, or hard; is easily broken; has a specific gravity of 2.5. According to Klaproth's analysis of it, it is composed of silex 57.25, argil 23.5, oxide of iron 3.25, manganese 0.25, soda 8.10, and water 3.

WACKE is intimately connected with basalt, and forms an intermediate substance between it and clay. Its colour is greenish-grey, with shades of brown or red; it has scarcely any lustre, and is opaque; its fracture is even; it is soft, and easily broken, and is liable to fall into pieces from exposure to the air. It occurs in large beds or masses, and often contains organic remains or impressions.

ARGILLACEOUS SLATE, or CLAY SLATE, the primitive slate of some mineralogists, forms extensive strata in connection with other primitive rocks, and likewise with those of transition. Its colour is grey, with various shades of blue, purple, and green; its lustre is weakly shining, or dull; it is opaque; its fracture is slaty, or foliated; its specific gravity is from 2.6 to 2.8. It has not been analysed with accuracy, but consists of silex, argil, lime, magnesia, and oxide of iron; the proportions varying in different specimens.

Other kinds of slate have been distinguished, with regard to which it may be doubted if they form proper chemical species; they pass into each other, and the limits of the divisions cannot always be accurately marked. Whet-slate, or Hone-stone, is distinguished from the other slates by its fracture, which is splintery, or scaly. Drawing-Slate is of a greyish-black colour, dull, opaque, and soft, so as to write and soil. Alum Slate is that which is distinguished by affording alum from exposure to the air. Bituminous Shale is of a brownish-black colour, with little lustre; is very soft, and feels a little greasy. Laid on burning fuel, it gives a weak flame and a black smoke; it appears to consist of clay with bitumen. Slate Clay forms the transition of these fossils into common clay; its fracture is slaty, approaching to earthy; it is opaque and dull; is soft; feels meagre, and adheres to the tongue; it softens and breaks down in water.

The term Clay is rather ambiguous, but is applied to those earthy mixtures, more or less indurated, which imbibe water, and may be kneaded with it into a paste somewhat ductile. Argil is the basis of all of them, or the earth which gives this predominating character; and it is mixed with various proportions of silex, magnesia, lime, and oxide of iron, the mixture being often merely mechanical, and giving rise to different varieties not easily accurately marked.

Indurated Clay, or Claystone, is clay in the highest state of induration. Its fracture is earthy, passing into even or slaty; it is soft, but is not easily diffused in water, and does not form with it a ductile paste; it is dull and opaque. The purest clay is that named Porcelain Clay, from the use to which it is applied; it occurs loosely indurated and earthy; its colour is white, with shades of grey, yellow, and red, without lustre or transparency; it feels soft; in water it falls to powder, and when kneaded forms a ductile paste. It is, in general, infusible by any heat that can be raised. It consists essentially of silex and argil; but the proportions of these vary considerably. Mr Wedgwood found the porcelain clay of Cornwall to be composed of 60 of argil, with 20 of silex; in others the silex is in larger proportion.

Potters' Clay occurs massive; its fracture is earthy; it is opaque, dull; generally of a yellowish or greyish-white colour; it soils, feels soft, and somewhat unctuous; adheres to the tongue; is diffusible in water, and forms with it a ductile paste. Pipe-clay is a variety of this. Loam is the same substance, mixed with sand, oxide of iron, and various other foreign and accidental substances. The Boles, which are of a red or yellow colour, are of similar composition, and appear to owe their colours to oxide of iron. They are distinguished by their conchoidal fracture. The Ochres are similar to the boles, containing only more oxide of iron. Lithomarge is distinguished by its greater fineness, being composed of scaly particles, with a surface more or less smooth and shining; it is soft and mild, feels greasy, and adheres to the tongue. Fullers' Earth occurs massive, but little indurated; its fracture is earthy, sometimes uneven or slaty; without lustre or transparency; it is soft and mild, and does not adhere much to the tongue. In water, it falls to powder, without forming a ductile paste. Tripoli is found loose or indurated; its fracture is earthy; it feels harsh and dry; does not adhere to the tongue, nor soil; it moulders in water, but does not form a ductile paste. It is used for polishing the metals and glass.

Native Alum, a saline product, is to be regarded as belonging to the argillaceous genus, argil being its base, united with potash and sulphuric acid. It occurs generally as an efflorescence, either in the state of a powder, or in slender silky crystals, and possessed of all the properties of the artificial salt.

Cryolite is a fossil which, from its composition, might be regarded as of a saline nature. It consists of argil with soda, combined with a large quantity of fluoric acid. It has, however, no solubility in water, and is quite insipid. It occurs massive, is of a white colour, with not much lustre, and only translucent. Its fracture is imperfectly foliated; its specific gravity is 2.9. It melts before the blowpipe, and then hardens. It dissolves in sulphuric acid, fluoric acid gas being disengaged. Klaproth finds it to consist of fluoric acid and water 40.5, soda 36, and argil 23.5.

Sect. VI.—*Of Glucine Fossils.*

In the fossils which may be placed under this genus, silex is the earth present in largest quantity, but glucine is the one which gives the predominating character, as is well displayed in the interesting fact which led to the discovery of this earth, that in the beryl and the emerald, the two principal fossils belonging to it, the primitive form of the crystals is the same.

The OCCIDENTAL EMERALD forms the species to which the name of Emerald is properly applied. It occurs crystallized, in short six-sided equiangular prisms, perfect or truncated on the edges lateral or terminal, or on the terminal angles. Its colour is that pure and rich green, which has derived from it the name of Emerald Green; its lustre is resplendent and vitreous; and it varies from translucent to transparent; its fracture is small conchoidal; it is hard, but much less so than the preceding gems; its specific gravity is 2.6 or 2.7. It is melted, though with difficulty, by the blowpipe into a white glass. It consists, according to Vauquelin's analysis, of silex 64.5, argil 16, glucine 13, oxide of chrome 3.25, lime 1.6, water 2.

BERYL is so analogous in properties and composition to the emerald, that it may be doubted if they are not varieties of the same species, chrome only being wanting, to which is probably to be ascribed the absence of the rich green colour of the emerald. Its colour is pale green, which passes into blue or yellow. It occurs in crystals of the same forms as the emerald; their lustre is shining and vitreous; and they are usually transparent; the fracture is imperfectly conchoidal; the hardness superior to that of quartz; the specific gravity is 2.6 or 2.7. The beryl is melted with difficulty before the blowpipe alone. According to Vauquelin's analysis of it, it is composed of silex 68, argil 15, glucine 14, lime 2, and oxide of iron 1.

With these species, the fossil, which has received the name of Euclase, is connected, its composition being similar to that of the beryl; its analysis, according to Vauquelin, affording silex 36, argil 19, glucine 15, iron 3, with 27 of loss. It occurs crystallized. Its colour is green; its lustre resplendent and vitreous; it is transparent; the fracture is foliated; the hardness superior to that of quartz, with much brittleness; the specific gravity 3.0. It loses its transparency before the blowpipe, and melts into a white enamel.

SECT. VII.—*Of Siliceous Fossils.*

THE siliceous fossils can scarcely be distinguished by any common characters, but are connected in a great measure from their chemical relations.

QUARTZ may be placed at the head of the genus, as consisting almost entirely of silex. Analysed by Bergman, it was found to be composed of 93 of silex, 6 of argil, and 1 of oxide of iron. When perfectly transparent, it is named Rock Crystal. It occurs crystallized; the perfect form of its crystals being the six-sided prism acuminated at both extremities by six planes, set on the lateral planes; but sometimes the prism is wanting, or nearly so, and then the form is the double six-sided pyramid, and frequently the single six-sided pyramid only is apparent. It occurs also massive and disseminated. Its most common colour is white; it also occurs brown, and more rarely yellow and red. Its lustre is highly vitreous; it is transparent, or semi-transparent. Its fracture is splintery, or conchoidal; it is hard, so as to give sparks with steel; its specific gravity is 2.6. It is infusible before the blowpipe, and is imperfectly softened by the heat excited by a stream of oxygen gas. It is a fossil extremely abundant, and of extensive distribution.

When quartz is of a purple colour, it has received the name of AMETHYST. ROSE QUARTZ, or Milk Quartz as it has been named, usually of a rose-red colour, sometimes milk-white, is another variety, as is the fossil named PRASE, distinguished by its leek-green colour.

CHRYSOPRASE is a pure siliceous fossil, containing, according to Klaproth, in 100 parts, 96.16 of silex, with 0.83 of lime, and one of oxide of nickel. Its colour is apple-green; it has little lustre; is translucent or semi-transparent; its fracture is even; its specific gravity 3.2. Before the blowpipe it loses its colour, but does not melt.

OPAL is a siliceous fossil not less pure. In the Noble or Perfect Opal, Klaproth found the composition to be 90 of silex, with 10 of water; in the common opal, 94.5 of silex, 5 of water, and 1 of oxide of iron. The perfect opal is distinguished by the beautiful play of colours which it exhibits, green, red, blue, and yellow of numerous shades, varied according to the position. Its proper colour is milk-white; its lustre is splendent and vitreous; it is translucent; its fracture is conchoidal. The common opal has the same characters, but does not present the beautiful effulgence of colours of the precious opal. The semi-opal has less lustre and transparency, is more dense, hard, and heavy, and contains a large portion of oxide of iron. Some varieties of opal, which appear to have lost the water they contain from exposure to the air, and in consequence have become opaque, recover their transparency when immersed in water. These have been named Hydrophanes. The fossil named Cat's Eye, from its property of reflecting in certain directions a changeable whitish effulgence similar to the eye of a cat, appears to belong to the same family.

Chalcedony is a species which has relations with the preceding fossils, and is of similar composition, containing 84 or 86 of silex, with from 4 to 16 of argil, and a trace of lime and oxide of iron. It occurs massive, frequently in nodules, botryoidal, stalactitic, and in other imitative shapes, sometimes in veins. Its colours are white, with shades of blue, grey, and yellow; and these are often arranged in stripes parallel or concentric; it has not much lustre, but is susceptible of a fine polish, from which lustre is acquired; it is semi-transparent or translucid; its fracture is even; it is hard, so as to strike sparks with steel; its specific gravity is 2.6. Carnelian is a variety distinguished principally by its red colour and conchoidal fracture. Cacholong is chalcedony of a milk-white colour. Onyx is that variety in which stripes of different colours alternate. Chalcedony stained with dark-coloured spots, veins, or arborizations, forms the Mocho stone. To this species may also be referred the greater number of Agates, as chalcedony is generally their basis, there being intermixed with it jasper, quartz, flint, or other siliceous fossils, forming a blended mass.

Flint is a very pure siliceous fossil; the silex in its composition amounting to 97 or 98 in 100 parts, with minute traces of argil, lime, and oxide of iron. It occurs in nodules, imbedded in chalk or limestone; its colour is grey, of various shades, passing into yellow, and brown or black; its lustre is weakly shining; in thin pieces it is translucent; its fracture is very perfectly conchoidal; its fragments sharp-edged; its hardness such that it gives copious sparks with steel. It is infusible before the blowpipe, but loses its colour. It is phosphorescent from friction. Flint Slate, or Siliceous Schistus, approaches to flint in colour, lustre, transparency, and hardness, and is distinguished by its fracture, which is slaty.

HORNSTONE, or PETROSILEX, is allied to these. Its colour is grey; it is dull, and only translucent on the edges; its fracture is splintery, or conchoidal; its fragments are sharp-edged. Like the preceding fossils, it is infusible before the blowpipe, and, according to Kirwan's analysis, contains more argil. Under this species is placed the siliceous petrified wood, or Woodstone, this being composed of the matter of hornstone, introduced, by slow infiltration, into the substance of wood, while the vegetable matter, by a slow decomposition, has been removed. It retains the appearance of the ligneous texture, and often its organic form.

JASPER.—In this fossil the proportion of argil to silex becomes larger, and in some varieties increases so much, that there is a transition to indurated clay; it also contains oxide of iron. Its colours are numerous, and generally dark; the most common are red, yellow, and brown; its lustre is weakly shining; and it is opaque, even on the edges. Its fracture is more or less perfectly conchoidal; it is inferior in hardness to flint, but still is not scratched by the knife; its specific gravity is from 2.3. to 2.7. Riband Jasper, or Striped Jasper, is distinguished by its colours being arranged in stripes generally straight. The Egyptian Pebble, which occurs in nodules, and exhibits various shades of colour, generally brown, in concentric stripes, is also a variety of jasper. Heliotrope, or Bloodstone, though ranked as a distinct species, differs little from jasper. Its colour is green, generally marked with small crimson-red spots.

Pitchstone has received its name from the resemblance in lustre and texture which it frequently has to pitch. Its colours are green, brown, red, and black; its lustre is shining, and resinous; it is translucent on the edges; its fracture is imperfectly conchoidal; it is moderately hard, and very brittle. It is fusible before the blowpipe, by which it is distinguished from any varieties either of opal or jasper. Its analysis by Klaproth gave 73 of silex, 14.5 of argil, 1 of lime, 1 of oxide of iron, 1.75 of soda and 8.5 of water. From pitchstone, there is a transition to what has been called Pearlstone, and from that to Pumice, both of which occur vesicular, have a shining pearly lustre, and are brittle, soft, and light. They are also of similar composition. Obsidian is also related to them. It is of a deep black colour; its lustre is highly splendent and vitreous; its fracture is large conchoidal; its fragments sharp-edged; its specific gravity is 2.3. It melts before the blowpipe into an opaque spongy glass. It is composed of 69 of silex, 22 of argil, and 9 of oxide of iron.

Feldspar is an important fossil, from its extensive distribution, as a component part of several aggregate rocks.

Foliated or Common Feldspar occurs massive, disseminated, and frequently crystallized; its crystals being prisms of four or six sides, variously modified. It colours are numerous, principally red, white, and grey; its lustre is shining, and intermediate between vitreous and pearly, and is varied, according to the position with regard to incident light: it is more or less translucent; its fracture is foliated, and its fragments rhomboidal. It is moderately hard, so as to scratch glass. Its specific gravity is from 2.2 to 2.5. It melts before the blowpipe into a white glass. Its analysis has given very different results, but silex and argil are always its chief constituents, with small proportions of magnesia, lime, potash, and oxide of iron. Some varieties of feldspar decompose from exposure to the air, become earthy, and at the same time lose their fusibility; a change probably produced by the removal of some of their principles, perhaps of potash or lime, by the infiltration of water.

Foliated Feldspar enters into the composition of many of the most important aggregate rocks, and in those of every formation. Granite consists of it, intermixed with quartz and mica, and the feldspar almost always forms the principal part or basis of the granite. Gneiss is the same aggregate, having a slaty texture; and Siennite is characterised by the addition of hornblende to the other ingredients. Greenstone is an aggregate of feldspar and hornblende alone: and the name of Porphyry is appropriated to that rock where grains or crystals of feldspar are imbedded in a certain basis, as in hornstone, pitchstone, or indurated clay.

Adularia is a variety of foliated feldspar, distinguished from the common variety by a greater degree of lustre, which is pearly, and reflected from the internal plates, so as to give in different positions a silvery appearance, by more transparency, and rather greater hardness. Labradore Feldspar is distinguished by the property of reflecting in certain positions, as the light falls upon it, very beautiful colours, particularly blue, green, and red; a property probably arising from decomposition, and the consequent alteration of its lamellæ. Compact Feldspar has less lustre and transparency; its fracture is splintery, fine grained, or very imperfectly foliated; and its fragments are not rhomboidal; its hardness is also inferior. It is allied to common feldspar, however, by its general relations, and its chemical characters.

JADE, the NEPHRITIC STONE of mineralogists, appears to approach to compact feldspar. The greasy polish which it receives had caused it to be classed among the magnesian fossils; but late analysis has shewn that it contains no magnesia; its composition being silex 53.75, lime 12.75, argil 1.5, oxide of iron 5, oxide of manganese 2, soda 10.75, potash 8.5, water 2.25. It occurs in rounded masses; its colour is leek green, which passes into greenish-white or light yellow; it is dull and nearly opaque; it is hard and difficult to break; is slightly unctuous to the touch. Before the blowpipe it melts into a white semi-transparent glass. BILDSTEIN, the figure stone of the Chinese, appears to belong to the same species; its characters are not very dissimilar, and it is of nearly the same composition, its constituent parts, according to Klaproth's analysis, being silex 62, argil 24, lime 1, oxide of iron 0.5, water

10, with a little potash, as ascertained by Vauquelin. The Axe-stone, which has derived its name from being used by the natives of the South Sea in making hatchets, is probably also a variety of the Bildstein.

Zeolite is well distinguished as a species by two chemical characters. It fuses with intumescence before the blowpipe into a white spongy glass, and it dissolves in acids, the solution being gelatinous. The Radiated variety occurs in mass, more frequently crystallized in four-sided prisms or tables. Its colour is white, with shades of grey, yellow, or red; its lustre shining and pearly; it is translucent and semi-transparent. Its fracture is radiated; the rays being generally diverging, and broad or narrow; the narrow radiated passes into fibrous, as on the other hand the broad radiated passes into a variety which is foliated; it is semi-hard, brittle, and light, its specific gravity seldom exceeding 2. The species appears to consist essentially of silex and argil, with a smaller proportion of lime, and a considerable quantity of water. From the analysis of the different varieties, the proportions are from 50 to 58 of silex, from 17 to 29 of argil, from 6 to 9 of lime, and from 10 to 22 of water. When acted on by acids, the lime and argil are dissolved, while the silex, in minute particles, and probably in combination with water, being diffused through the liquid, gives the gelatinous consistence. The intumescence before the blowpipe is probably owing to the expulsion of the water from the fused matter.

Cubizite, or Analcime, was formerly known by the name of Cubical Zeolite, but it appears to be a distinct species. The form of its crystals is the cube, perfect or acuminated on each angle by three planes. Its colour is white; its lustre splendent and vitreous; it is transparent, or semi-transparent; its fracture is imperfectly foliated; is harder than zeolite, so that it scratches glass; it is also heavier, and does not form a jelly with acids. **Needle-Stone**, which had been regarded as a zeolite, has also been formed into a distinct species, probably without any sufficient reason; it differs from the radiated zeolite, in being much harder and more brittle; and in its lustre being greater, and of the vitreous kind.

Prehnite has some of the characters of zeolite, but is distinguished by being harder and heavier, and by not forming a jelly with acids. It occurs massive, and crystallized in quadrangular prisms, and oblique four-sided or six-sided tables, often aggregated. Its colour is green; its lustre is shining; it is of various degrees of transparency; its fracture is foliated, or radiated; it is hard, so as to scratch glass; its specific gravity is from 2.6 to 2.9. It melts before the blowpipe with intumescence. Klaproth found it to be composed of 43.83 of silex, 30.33 of argil, 18.33 of lime, 5.66 of oxide of iron, and 1.83 of water.

Natrolite belongs to this family. It occurs massive, and, in its fracture, presents straight or diverging fibres; its colour is light yellow, with little lustre; it is translucent on the edges, and is nearly of the hardness of prehnite. It fuses very readily before the blowpipe, and contains not less than 16 of soda in 100 parts.

Lazulite.—Lapis Lazuli, or Azure Stone, is of a rich azure-blue colour, approaching sometimes to sky-blue;

with little lustre, and only translucent on the edges. It occurs massive; its fracture is uneven or earthy; it is so hard as to scratch glass; its specific gravity is 2.7. It melts before the blowpipe into a white enamel, and, if previously calcined, is soluble in acids, forming a jelly. Klaproth found it to be composed of 46 of silex, 14.5 of argil, 28 of carbonate of lime, 6.5 of sulphate of lime, 3 of oxide of iron, and 2 of water. It is used in Mosaic work, and its powder affords the valuable paint known by the name of Ultramarine.

STAUROLITE, or Cross Stone, derives its name from occurring in twin crystals, (rectangular four-sided prisms acuminated by four planes), which intersect each other, so that the double crystal has the appearance of a cross. It occurs also in single crystals of the same form. Its colour is white; its lustre shining and vitreous; it is translucent, or semi-transparent. Its fracture is foliated; it is hard; its specific gravity 2.3. It melts before the blowpipe, and is phosphorescent when thrown on burning fuel. It consists of 40 of silex, 16 of argil, 18 of barytes, and 15 of water.

GARNET occurs both massive and crystallized: the forms of its crystals are the dodecaedron, with rhomboidal planes, either perfect, or truncated on all its edges, giving 36 faces. The variety named the precious garnet is almost always crystallized; the common is often massive. The former is of a red colour, of various shades; the lustre is more or less shining, and is vitreous; it varies in transparency from completely transparent to translucent; its fracture is conchoidal; it is harder than quartz, so as to scratch it; its specific gravity is from 4 to 4.3; it is therefore one of the heaviest of the earthy fossils. The common garnet has less lustre and transparency, and its colours are deeper; it is also inferior in hardness and specific gravity. Both varieties are melted before the blowpipe. They consist of silex and argil, with a large proportion of oxide of iron.

Leucite, a fossil which occurs imbedded in lava, was, from the appearance of its crystallization, named White Garnet; but it differs altogether in its characters. Its colour is white, with a yellowish or greyish tinge; its internal lustre is shining, and somewhat vitreous; the crystals vary from opaque to transparent; its fracture is foliated; its specific gravity is 2.4. It is not fused before the blowpipe. It consists of 54 of silex, 24 of argil, 21 of potash, and 2 of lime.

Vesuvian is crystallized in rectangular four-sided prisms, more or less deeply truncated on all its edges. Its colour is olive-green, passing into yellow, or brown; its external lustre is splendent and vitreous; it is translucent; its fracture is small-grained uneven; it is harder than quartz; its specific gravity is from 3.3 to 3.5. It melts before the blowpipe into a yellowish glass. It consists of silex 35.5, lime 33, argil 22.25, oxide of iron 7.5, oxide of manganese 6.25.

Olivin occurs in grains or rounded pieces, or sometimes, though rarely, crystallized in rectangular four-sided prisms. Its colour is green, of different shades; its lustre is shining and vitreous; it is semi-transparent; its fracture is small conchoidal; it is inferior in hardness to quartz; its specific gravity is 3.2. It consists of silex from 40 to 50, of magnesia from 37 to 38, lime 20.5, oxide of iron

12.5. With this fossil the CHRYSOLITE has been united by Haüy: in composition they are nearly the same; and in colour, lustre, hardness, fracture, and forms of crystallization, they are similar. AUGITE has also considerable resemblances to olivin, and is frequently found with it. It differs in the form of its crystals, which is a rectangular six-sided prism bevelled on the extremities; in its colour being a darker green, approaching to black; in being harder and heavier, the specific gravity being from 3.4 to 3.7. It is composed of 52 of silex, 13.2 of lime, 3.33 of argil, 10 of magnesia, 14.66 of oxide of iron, and 2 of oxide of manganese.

THUMERSTONE, or VIOLET SCHORL, occurs generally crystallized in very flat and obscure rhombs. Its colour is clove-brown, which passes into violet, or into grey; its external lustre is splendent, and it varies from transparent to translucent; its fracture is uneven; it is nearly of the hardness of quartz: its specific gravity is 3.2. It melts before the blowpipe, into a semi-transparent greenish glass. It consists of 44 of silex, 18 of argil, 19 of lime, 14 of oxide of iron, 4 of oxide of manganese.

SCHORL is of a black colour, with a lustre which is weakly shining, and is generally opaque, or slightly translucent on the edges. It occurs massive, and frequently crystallized in prisms; its fracture is imperfectly conchoidal, or uneven; its hardness is a little inferior to that of quartz; its specific gravity is 3. It melts with ebullition before the blowpipe into a greyish slag. It is distinguished by becoming electric by heat, presenting at one extremity positive electricity, at the other negative. The

Tourmalin is very nearly allied to schorl, and is chiefly distinguished from it by its colours, which are brown, green, red, and blue, of numerous shades, generally dark, and by its greater lustre. It consists, according to Vauquelin, of 40 of silex, 39 of argil, 3.84 of lime, 12.5 of oxide of iron, and 2 of oxide of manganese.

PISTACITE, Epidote, or Thallite, has been ranked as a variety of actynolite; but in composition it approaches to the tourmalin, its analysis by Descostils affording silex 37, argil 27, lime 14, oxide of iron 17, oxide of manganese 1.5. It is usually crystallized in six-sided, or oblique four-sided prisms; is of a pistachio-green colour; the lustre is shining and vitreous; the crystals are more or less transparent; the fracture is foliated or radiated; it is hard and brittle.

SCHORLITE, having a considerable resemblance to schorl, was regarded as a variety of it; but it appears to be a distinct species. It is usually of a light yellow colour, which passes into deep yellow, green, or greenish-white, and also violet-blue and red. It occurs massive, or crystallized in long hexaedral prisms, more or less translucent, and having a shining lustre; its cross fracture is foliated; it is moderately hard and brittle. It consists, according to Klaproth, of 50 of argil, and 50 of silex; according to Vauquelin, of argil 52.6, silex 36.8, lime 33, and water 1.5.

Besides these fossils, silex is found deposited in a stalactitic form from waters, in which it has been previously in a state of solution. The deposite from the Geyser fountain is the principal example of this kind. It occurs in massive pieces; the surface sometimes botryoidal; its fracture is either compact or fibrous; it has scarcely any lustre; is of a greyish-white colour; and is only semi-indurated, so as to be easily broken. It consists, according to Klaproth's analysis, of 98 of silex, 1.5 of argil, 0.5 of oxide of iron. Similar deposites are formed from other mineral springs: in some siliceous stalactites, the surface is even covered with crystals of quartz.

Sect. VIII.—*Of Zircon Fossils.*

To the zircon genus of fossils belong two fossils in which this earth is found, the Zircon and Hyacinth. To these Werner has added another, from its external colours, the Cinnamon Stone.

Zircon or Jargon occurs in rounded or angular grains, and crystallized. Its principal colour is grey, but it has often shades of green, blue, yellow, and brown; its internal lustre is resplendent and adamantine; it is transparent; its fracture is small conchoidal; it is extremely hard, so as to be scarcely affected by the file; its specific gravity is 4.6 or 4.7. It does not melt alone before the flame of the blowpipe, but with borax added it forms a transparent glass. It consists of zircon 68, silex 31.5, oxide of iron 0.5. It is cut as a gem, and is sometimes sold for the diamond, as, when cut, it has a similar play of colours.

The Hyacinth occurs in grains, or crystallized; its principal colour is what has been named Hyacinth Red, but often with various other shades; its lustre is resplendent and resinous; it is transparent or semi-transparent;

dron, with rhomboidal planes: it is also found capillary, filiform, in thin plates or spangles, and sometimes massive; sometimes also in small grains in the sand of rivers and streams, forming what is named Gold Dust. Besides this, which is the common variety, there is one of a brass yellow colour, generally disseminated, or in small plates, in which the gold appears to be alloyed with silver and a little iron; and another of a steel-grey colour, passing to yellow, in which the proportion of alloy is greater.

Some minerals have been regarded as ores of gold, though they are not strictly so, as they contain larger quantities of other metals. The principal of these are the two native alloys of tellurium, the graphic gold ore, or graphic silvanite, and the white silvanite, which pass into each other. These consist of from 20 to 27 of gold, with from 45 to 60 of tellurium, 10 of silver, and sometimes a little lead. The alloy is in minute indeterminate crystals of a greyish-white colour, generally attached to each other laterally, and dispersed on the surface of the matrix, so as to bear some resemblance to printed letters; hence the name, graphic gold ore. Gold is also found in smaller quantity in some other ores, especially in some varieties of sulphuret of iron, or pyrites, which are hence named Auriferous, as well as in some of the other native sulphurets, in all which it is supposed to be merely disseminated without being combined.

SECT. II.—*Of Native Platina.*

PLATINA, like gold, is found only in the metallic form. It has not been found in the original repository, but in the sand of certain streams, and this forms what is named Native Platina, hitherto discovered only in South America. It is in the form of grains, but pieces have been found of a greater size. Its colour is white, approaching to a light steel-grey; its lustre metallic and shining. It is semi-hard, perfectly malleable, flexible, and has a specific gravity above 15. It is the least fusible of the native metals, not melting except in a heat such as that excited by a powerful burning mirror, and it is soluble only in nitro-muriatic acid.

SECT. III.—*Of Ores of Silver.*

SILVER is found native, and also mineralized. Native silver has the general qualities of the metal. Its colour is white, though frequently tarnished; its lustre metallic; it is perfectly malleable and ductile, usually flexible; it is soft; its fracture is hackly. It occurs massive, branched, capillary, in thin plates, and crystallized; the crystals being generally small and aggregated.

By an alloy of antimony with silver, characters are acquired sufficiently distinctive to form a species, which has been named Antimonial Silver. It differs from the preceding in having less external lustre, in its colour being tin-white, its fracture being lamellated, and in being brittle. It consists of from 67 to 84 of silver, with from 24 to 16 of antimony. Another native alloy of silver, forming a species, is that with arsenic, containing also sometimes iron and antimony, named Arsenical Silver. Its colour is tin-white, which is always tarnished, and often approaches to grey. Its external lustre is weakly shining; its fracture is foliated; it is soft and brittle. It occurs massive, disseminated, and crystallized; the forms of its crystals being the six-sided prism or pyramid. Before the blowpipe it exhales vapours of arsenic and antimony. It consists of 35 arsenic, 44.25 iron, 12.75 silver, and 7 of antimony.

Silver mineralized by sulphur, forms the Vitreous Silver Ore, or Silver Glance; Sulphuretted Silver. Its colour is lead-grey, passing to steel-grey; its lustre is shining, or glistening, and metallic; its fracture is uneven; it is soft, so as to be cut by the knife, malleable and flexible; its specific gravity is about 7.200. It occurs massive, disseminated, of various imitative shapes, as filiform, and in minute crystals. It consists of about 84 of silver, with 16 of sulphur.

The name of Red Silver Ore is given to a species, which, from its composition, may be named Sulphuretted Antimonial Silver. Its colour is red, of various shades; its lustre is shining, and metallic or adamantine; when massive, it is opaque; when crystallized, transparent or semi-transparent; its fracture is uneven, is soft and brittle; has a specific gravity from 5.56 to 5.59. It occurs massive, disseminated, dendritic, and minutely crystallized. Heated on charcoal by the blowpipe, it decrepitates, melts, exhales a white vapour having an unpleasant odour, and gives a globule of silver. It consists, according to Vauquelin's analysis, of silver 56.67, antimony 16.13, sulphur 15.07, and oxygen 12.13, this oxygen, as he supposes, being divided between the metals, forming oxides, with which the sulphur is combined.

Grey Silver Ore, as it has been named, can scarcely be regarded as an ore of silver, since it contains not more than from 9 to 20 parts of silver in 100 parts, while it contains from 40 to 48 of lead, and from 8 to 21 of antimony. It consists besides of from 12 to 22 of sulphur, 1 or 2 of iron, from 1 to 7 of argil, and a minute trace of silex. There are two varieties of it, the light grey, or white silver ore, the colour of which is a light lead grey; its lustre shining and metallic, and which occurs always massive or disseminated; and the dark-grey silver ore, the colour of which is iron grey, passing to black, without lustre; and its fracture is earthy. They pass into each other, and into the other native metallic sulphurets.

Silver mineralized by muriatic acid, forms a well-defined species, Horn Silver Ore, as it has been named. Its colour is pearl-grey, of various shades, passing into white or blue; externally, its lustre is shining; it is translucent, gives a shining streak; is soft, so as to be easily cut, is also malleable; its fracture is fine grained uneven, specific gravity about 4.7. It occurs rarely massive, more frequently crystallized; its crystals being acicular, or cubes which are aggregated. Heated before the blowpipe it melts, exhales a disagreeable odour, and gives a globule of silver. Another characteristic chemical character of it is, that when breathed on, and rubbed by a piece of iron or zinc, the rubbed surface exhibits a thin film of reduced silver. It consists of silver 67.75, muriatic acid 21, sulphuric acid 0.25, oxide of iron 6, argil 1.75, lime 0.25.

These are the proper silver ores. This metal is likewise present in small quantity in other metallic ores; from which, from its commercial value, it is an object to extract it; but these do not properly belong to this genus.

SECT. IV.—*Of Ores of Quicksilver.*

THIS metal occurs native and mineralized. Native Quicksilver is found in globules, on the surface, or in the crevices of other mercurial ores, or other fossils, retaining the lustre, opacity, mobility, and other properties of the pure metal Sometimes it has an alloy of silver, so as to give a soft, and even a firm consistence; and when the proportion of silver is large, it forms a proper species, which occurs in a crystallized form, having the general qualities of the metals of which it is composed. It exhales the quicksilver in vapour when exposed to the heat of the blowpipe, and the silver remains.

Quicksilver in the state of oxide combined with muriatic, and a portion of sulphuric acid, forms the species which has been named Mercurial Horn Ore. This generally occurs in small crystals. Its colour is grey, with a pearly lustre. It is faintly translucent: its fracture is foliated; it is soft and brittle, so as to be easily scraped, or cut with a knife. Before the blowpipe it is volatilized.

Quicksilver mineralized by sulphur, forms Cinnabar, its most abundant ore. Its colour is red, of various shades; its lustre various, passing from shining to dull. It occurs massive, disseminated, and crystallized, the crystals being always small. When crystallized, it is translucent or semitransparent; when massive, opaque. It is brittle and soft. Its specific gravity varies from 6 to 10. Heated by the blowpipe, it is volatilized, with smoke, a blue flame, and an odour of sulphur. It consists, when free from foreign matter, according to Klaproth's analysis, of 84.5 of quicksilver, and 14.75 of sulphur.

Hepatic Quicksilver Ore occurs massive. Its colour is intermediate between dark-red and lead-grey, or iron-black. It has little lustre, and is perfectly opaque. Its fracture is even or slaty. It is soft, brittle, and has a specific gravity of from 7 to 9. Its nature was not well ascertained, until it was examined by Klaproth, who has given as the results of the analysis,—quicksilver 81.8, sulphur 13.7, charcoal 2.3, silex 0.65, argil 0.55, oxide of copper 0.2, water and loss 0.7. It is probably cinnabar, altered by the intermixture of small quantities of foreign substances.

SECT. V.—*Of Ores of Copper.*

COPPER occurs native, and likewise mineralized, forming several species of ores, in general well defined.

Native Copper has the general properties of the pure metal. Its colour is red, but frequently tarnished: its lustre metallic; it is flexible, ductile, and malleable; its fracture, like that of other metals, is hackly. Its specific gravity is from 7.6 to 8.5. It occurs massive, in branched pieces, dendritic, in thin plates, and indistinctly crystallized.

Copper mineralized by oxygen, forms Red Copper Ore, of which what is named florid red copper ore is the purest form. It occurs massive, in plates, disseminated, and crystallized. Its colour is cochineal-red, of various shades, approaching to carmine-red; its lustre is semi-metallic, or adamantine; it is opaque when massive; transparent, or semi-transparent, when crystallized; it is semi-hard, brittle; its specific gravity is about 3.9. Its fracture is compact, foliated, or fibrous; whence different varieties are formed. It appears to be pure oxide of copper; consisting, according to Chenevix's analysis of it, of about 88.5 of copper, and 11.5 of oxygen. The brick-red or tile-red copper ore, which occurs earthy or little indurated, appears to be a mixture of oxide of copper and oxide of iron.

Oxide of copper combined with carbonic acid, appears to form two natural species, the Blue Carbonate and the Green Carbonate; the differences between which arise probably from different states of oxidizement of the metal, or perhaps in part from the combination of water.

The Blue Carbonate is known under the name of Mountain Blue. One variety is earthy, usually forming an incrustation, sometimes massive, the colour of which is smalt blue without any lustre. The other is indurated; its principal colour is azure-blue; when crystallized, its lustre is shining and glassy; when massive, it is rather dull; the latter is opaque, while the crystals are translucent, or semi-transparent; the forms of its crystals are the rectangular and the rhomboidal four-sided prism, acuminated by four planes; they are small and aggregated. This species dissolves in nitrous acid with effervescence. Analysed by Pelletier, its constituent parts were from 66 to 70 of copper, from 8 to 10 of oxygen, from 18 to 20 of carbonic acid, and 2 of water.

The Green Carbonate of copper comprises two varieties, what have been named Mountain Green, and Malachite. The first is massive, but more generally occurs as an incrustation; its colour is verdegris-green; it is generally dull; its fracture is earthy or small conchoidal; and it is soft and brittle; it effervesces, though slightly, with acids, and appears to consist of oxide or carbonate of copper, with argil and lime. The other variety, Malachite, occurs massive, disseminated, incrusting, and crystallized in capillary and acicular prismatic crystals; its colour is green; its lustre is silky or pearly; its fracture striated, the striæ being usually divergent. One variety has a compact fracture. This species effervesces with acids. The fibrous malachite analysed by Klaproth was found to consist of 58 of copper, 18 of oxygen, 12.5 of carbonic acid, and 11.5 of water. It contains therefore more oxygen and more water than the blue carbonate.

Copper mineralized by phosphoric acid forms a rare ore, formerly confounded with malachite, but analysed by Klaproth, and found to consist of oxide of copper 68.13, phosphoric acid 30.95. It occurs massive, disseminated, in cubic crystals very small and grouped, of a green colour, often black on the surface, with a vitreous lustre, and opaque: its fracture is fibrous.

Copper occurs also mineralized by muriatic acid: This fossil was first observed in angular grains; it has since been obtained massive, and crystallized in six and in four sided prisms, transparent, with considerable lustre; when massive, it is opaque. It dissolves in nitric and muriatic acids without effervescence, and distilled with sulphuric acid, exhales muriatic acid. Analysed by Klaproth and Proust, it has given nearly the same results, from 70 to 76 of oxide of copper, about 10 of muriatic acid, and from 12 to 16 of water.

Sulphate of copper occurs in solution in the water of some copper-mines; and sometimes deposited stalactitic or crystallized; its crystals being either capillary, or cubes truncated on the edges or angles, of a blue colour, shining and translucent.

Copper occurs mineralized by arsénic acid, forming combinations which differ with regard to proportions, and the presenee of water; giving rise to several varieties, which have even been regarded as distinct species, and the composition of which has been established by Chenevix. There is one which occurs crystallized, in the form of an obtuse octaedron. Its usual colour is sky-blue; though sometimes it is of an apple or grass green; it is translucent, shining; it is brittle; has a specific gravity of 2.881. It consists of 49 of oxide of copper, 14 of arsénic acid, and not less than 35 of water. A second is crystallized in hexaedral tables, bevelled on the terminal planes; its colour is a deep emerald-green, with much lustre and transparency; it is less hard, and likewise less heavy; its specific gravity being only 2.548. It consists of 58 of oxide of copper, 21 of arsénic acid, and 21 of water. A third is crystallized in the form of an acute octaedron, the crystals sometimes being lengthened and capillary; frequently capillary and indeterminate; in some specimens appearing as delicate fibres parallel or divergent; and sometimes in layers, flat or mammillated, and of a fibrous texture. The colour in these different states is dark olive-green, often passing into brown or yellow, or greenish-white; it is generally transparent, or semi-transparent; the lustre is externally shining; it is harder than the preceding varieties, and is much heavier; the specific gravity being 4.280. It consists of from 50 to 60 of oxide of copper, from 30 to 40 of arsénic acid, with, in some varieties, water amounting to 18 or 20 parts. The last variety occurs crystallized in triedral prisms, generally extremely small; they are of a beautiful bluish-green colour, but from decomposition often black; when unaltered, they are transparent. Its specific gravity is 4.280. It consists of 54 oxide of copper, 30 arsénic acid, and 16 water.

Copper, in combination with sulphur, with variable proportions of several other metals, forms a series of ores, which pass into each other, and which it is difficult to arrange as distinct species, as it is not easy to determine whether some of them are aggregates or compounds of different metallic sulphurets, or whether two or more of the metals associated together are in immediate combination with each other, and with the sulphur. What is named Vitreous Copper Ore appears to be the sulphuret of copper in its purest form; it consists of 78.50 of copper, 18.50 of sulphur, 2.25 of iron, and 0.75 of silex. It occurs massive, disseminated, and crystallized, the forms of its crystals being numerous and often imperfect. Its colour is grey; its lustre metallic; its fracture is conchoidal or even, or foliated; its specific gravity is from 4 to 5.3. In the Purple, or Variegated Copper Ore, the proportion of iron is larger, and either it or the copper appears to be slightly oxidated. Klaproth's analysis gave of copper 69.5, of iron 17.5, of sulphur 19, and of oxygen 4 or 5. The colour of a fresh fracture is reddish-brown, but it quickly tarnishes; various tints of purple, blue, red, reddish-yellow, and green, being assumed and intermixed on the same surface. It occurs usually massive, sometimes disseminated; its lustre is shining and metallic, but is diminished with the tarnishing; it is opaque; is soft and brittle; its specific gravity from 4.3 to 4.9. Copper Pyrites is a compound of sulphur, copper, and iron; or, in another point of view, a combination of sulphuret of copper, and sulphuret of iron, and these are in various proportions. Its colour is brass-yellow, being deeper as the copper is more abundant in its composition; it is generally tarnished, and often iridescent. It occurs massive, disseminated, in botryoidal and stalactitic forms, and crystallized. Its lustre is shining and metallic; its fracture uneven; it is brittle, and has a specific gravity from 4.1 to 4.3. The last of these sulphurets is the Grey Copper Ore. It contains, combined with the sulphur and copper, various metals, lead, antimony, silver, and iron, in very variable proportions; and what proves it to be a proper sulphuret of copper, and that these are merely mixed with it, is that, when present, they do not materially modify its properties, and that it occurs composed of copper, iron, and sulphur alone; one specimen analysed by Chenevix having given 52 of copper, 31 of iron, and 14 of sulphur. It occurs massive, disseminated, and crystallized; the principal form of its crystals being the tetraedron or three-sided pyramid, variously modified. Its colour is steel-grey, which is liable to tarnish: its lustre is shining and metallic; its fracture uneven; it is brittle, and has a specific gravity from 4.4 to 4.8.

What is named White Copper Ore has not been accurately analysed, but it appears to contain arsenic, from the odour it exhales when heated by the blowpipe, in combination with copper, and probably iron, and sulphur. Its colour is white, with a shade of grey or yellow; its lustre is metallic; it is brittle, and has a fine-grained uneven fracture; it occurs either massive or disseminated, and is a very rare ore.

Sect. VI.—*Of Ores of Iron.*

Iron is of all metals the one of most extensive distribution. It occurs generally in the state of oxide, pure or combined with other substances, forming an extensive family of ores.

Besides these, the singular fact has been established, that it is a meteoric or atmospheric production, the stony masses which it has been established by the most ample evidence have fallen from the clouds at different periods, and in different countries, being composed principally of iron. As natural compounds of this metal, they may be considered in this place.

These meteoric stones are heterogeneous in their structure. They have externally a thin black crust. When broken, they are of an ash-grey colour, and granulated texture, and appear to be composed of four substances, which can be distinguished by a lens. One of these is in small globular or elliptical grains of a grey colour, having a conchoidal fracture, a lustre resembling that of enamel, and so hard as to scratch glass; this has a resemblance in characters and composition to the Chrysolite. Another consists of iron pyrites of a reddish-yellow colour, and granulated texture. The third consists of particles of iron in a metallic state, capable of being extended under the hammer, and giving to the entire stone the property of being attracted by the magnet. These three substances are united by a fourth, which is nearly of an earthy consistence. Mr Howard, some years ago, investigated the composition of these. Both the metallic pyrites and the iron contain nickel. The vitrified substance consists of silex, magnesia, oxide of iron, and a little nickel. The composition of the earthy matter is nearly the same, and it differs principally in aggregation. The external crust consisted of iron and nickel partially oxidized. In all the specimens the same elements were found, and in proportions not very different; and this agreement in fossils, found in countries so remote, is a proof of their common origin.

There is every reason to believe, that the large insulated masses of iron which have been observed in America and Siberia have had the same origin. Proust, in analysing a fragment of that from America, found it to contain nickel; and Mr Howard, on repeating the analysis, likewise ascertained this, 100 grains giving 7½ of nickel. That from Siberia he equally found to contain nickel. And both these masses have a vitrified matter, resembling chrysolite, intermixed in their substance, analogous to that present in the meteoric stones.

From a number of the accounts authenticated with regard to the fall of these masses, it appears that they have been highly heated, and probably in a state of fusion. The stone, when touched after its fall, has been felt quite hot, and the external crust has appeared newly vitrified. The fall has also been frequently accompanied with the appearance of a fiery meteor, as of a luminous ball, and sometimes with discharges of lightning, and with a loud noise, or repeated explosions.

With regard to the origin of these masses, it is extremely difficult to advance any hypothesis at all satisfactory. They have been supposed to be projected from volcanoes, a supposition refuted by the consideration of their entire dissimilarity to any known volcanic production, and of their fall in countries so remote from any volcanoes. La Place advanced the bold conjecture, that they have been projected from the moon, and endeavoured to shew by calculation, that a force might be exerted at the surface of that planet adequate to this effect,—a calculation involving, however, the gratuitous and improbable assumption, that the moon has no atmosphere, and liable to other objections. The more moderate hypothesis is obvious, that they may be the products of combinations in the upper regions of the atmosphere. But all such conjectures must of course rest on very hypothetical grounds.

The most abundant and most numerous ores of iron are those in which it is mineralized by oxygen, of which there is a series differing in the degree of oxidation of the metal, and in the intermixture of other substances. These may be arranged, principally from their chemical relations.

One species well defined is that named Magnetic Iron Ore, from its high magnetic power. It occurs massive and crystallized; the forms of its crystals being the cube, octaedron, and rectangular tetraedral prism. Its colour is black or deep-grey; its lustre is shining and metallic; and it is opaque: its fracture is uneven, or imperfectly foliated; it is brittle, and hard; its specific gravity is from 4.2 to 4.9: it is insoluble in nitric acid, but dissolves in muriatic acid, with the assistance of heat. It yields from 80 to 90 in 100 of iron, and may be regarded as a pure oxide. Sometimes it occurs in the form of small particles or grains, forming what is named Magnetic Iron Sand.

The next species is equally determinate,—that named Specular Iron Ore, or Iron Glance. In it the magnetic power is so far impaired by a higher degree of oxidizement, that it is attracted by the magnet only when in fine powder. It occurs massive, and frequently crystallized; the forms of its crystals being very numerous, and variously modified; its colour is steel-grey, but is often tarnished and iridescent; the lustre is highly shining and metallic; its fracture is uneven, sometimes foliated; it is so hard as to scratch glass, and is brittle; its specific gravity is from 4.6 to 5.2. It is insoluble in nitric acid, but dissolves in the muriatic acid, with the assistance of heat. It consists of from 60 to 80 of iron, and from 20 to 30 of oxygen. The Micaceous Iron Ore has been regarded as a variety of this species. It is massive, disseminated, or crystallized, in small and thin six-sided plates; is shining, and feels somewhat greasy, but without staining the fingers; and is not so hard as the specular iron ore; its fracture is foliated.

The next family of ores it is more difficult to arrange as species. The iron is in a higher state of oxidation, and the oxide is mixed with quantities of several other substances, principally argil, silex, and lime, but in such variable proportions, and passing so much into each other, that their specific distinctions can be only imperfectly determined. The principal of these ores are the Red Ironstone, Brown Ironstone, Black Ironstone, and Clay Ironstone.

Of Red Ironstone, there are two principal varieties, the compact red ironstone, the fracture of which is even; and the hæmatite, the fracture of which is fibrous, the fibres being straight, parallel, or diverging. The former occurs generally massive, or in detached masses, nodular, or stalactitic, the latter almost always in globular or kidney-shaped masses, stalactitic or botryoidal. The colour of both is intermediate between brownish-red and steel-grey; but in the streak, and in powder, always blood-red. Their specific gravity is from 3.5 to 5. Brown ironstone is distinguished from the red, principally by the colour being brown in the mass, and in the streak yellow, or yellowish-brown. Of it, too, there are two principal varieties, distinguished by the fracture,—the compact brown ironstone, the fracture of which is even; and the brown hæmatite, the fracture of which is fibrous, the fibres being in general diverging. The compact occurs massive, sometimes in masses of various imitative forms. The fibrous occurs generally in masses, stalactitic, kidney-shaped, or botryoidal. The colour of both is brown, of various shades and intensities; sometimes tarnished, so as to be iridescent, with a degree of lustre that is semi-metallic; the specific gravity is about 3.4 or 3.5. The analysis of these has not been executed with any accuracy, but they appear to contain, with oxide of iron, argil, lime, and, as has been supposed, oxide of manganese. They yield from 40 to 60 of iron, in general of excellent quality, from 100 of ore. With these are connected the less important varieties of Scaly Iron Ore, and of Iron Ochre;—the former generally incrusting the other ores of the species, or lining their cavities, and, being composed of scaly particles, which have a shining lustre, soil, and feel unctuous; the latter being earthy and little indurated, of a red or yellowish-brown colour, dull, and staining the finger.

Black Ironstone, like the red and brown, comprises two principal varieties,—the compact, and the fibrous or black hæmatite. Its colour is bluish-black, or dark steel-grey, with a semi-metallic lustre. It occurs massive, and in tuberose, kidney-shaped, and botryoidal pieces. Its composition is not known, but it is supposed to contain a large proportion of oxide of manganese.

Argillaceous Iron Ore, or Clay Ironstone, comprises a series of ores, in which oxide of iron is mixed with a large proportion of argil or clay, the limits of which are not easily marked, as they pass into each other. The common argillaceous ironstone occurs massive, generally in beds or strata. Its colour is grey, of different tints, which passes into various shades of a yellowish or reddish-brown, especially from exposure to the air; it has no lustre, and is perfectly opaque; its fracture is earthy; sometimes even; sometimes inclining to slaty; it is soft, feels meagre, adheres a little to the tongue; its specific gravity is about 3.3 or 3.4. It consists of oxide of iron, clay, with portions of lime and silex; and affords from 30 to 40 of iron in 100, of good quality. Nodular Ironstone, reniform iron ore, or eagle stone, belongs to this species; it occurs in rounded masses, sometimes spherical, generally somewhat oblate, or approaching to the kidney form; composed of concentric lamellar concretions, and sometimes inclosing a nodule slightly adhering or quite loose. Pisiform Iron Ore is a similar variety, in small rounded grains, whence its name; of a yellowish-brown colour, having an earthy fracture, with little coherence. It has been analysed by Vauquelin, and gave 30 of iron, 18 of oxygen, 31 of argil, 15 of silex, and 6 of water.

Sparry Iron Ore is a species well determined from its chemical relations. It consists of oxide of iron, oxide of manganese, and carbonate of lime. The proportions vary, and the carbonate of lime augments in some varieties so much, that they are placed among the calcareous fossils, forming the Pearl Spar; and it is only when the proportion of metallic matter is abundant, that it is regarded as an iron ore. It occurs massive, disseminated, and crystallized; the forms of its crystals being the rhomb, perfected or truncated, the lens, the octaedron, and the dodecaedron. Its colour is white, grey, yellow, or brown; but what is a peculiar property of it, the colour darkens from exposure to the air: it thus becomes brown, and at length black,—a change owing to the manganese existing in it in a low state of oxidizement, and absorbing oxygen from the atmosphere; its lustre is pearly; it is translucent on the edges: its fracture is foliated: its fragments are rhomboidal; it is harder than calcareous spar, so as to scratch it; its specific gravity is from 3.6 to 3.8; it is soluble with effervescence in acids. It blackens before the blowpipe, and loses weight. Analysed by Bergman, it afforded in different specimens, from 22 to 38 of oxide of iron, from 24 to 28 of oxide of manganese, from 19 to 24 of lime, from 10 to 17 of carbonic acid, and from 9 to 6 of water. Descostils has found magnesia in it. It is considered as affording the iron best adapted to the manufacture of steel.

Oxide of iron deposited from water, holding it in solution, and stagnant in swampy situations, forms Bog or Swamp Iron Ore, which is in different degrees of induration, in masses which are corroded, cellular, and sometimes tuberose, of a yellow or brown colour, dull, and earthy. With oxide of iron, those ores have been supposed to contain argil, silex, and phosphoric acid. Vauquelin, with these ingredients, discovered in them lime, magnesia, manganese, and chrome. Blue Iron Earth is probably of similar origin, as it is associated with bog iron ore, and, according to Haüy, consists of oxide of iron, with argil, and a little phosphoric acid; though Vauquelin found in it only oxide of iron, argil, and silex. It is at first of a white colour, but becomes blue from exposure; is loose and friable, without any lustre. Green Iron Earth has likewise been supposed to consist of iron and phosphoric acid. It is earthy, more or less coherent, of a green colour, without lustre. An ore of this family, in which the presence of phosphoric acid is less ambiguous, has been analysed by Vauquelin, and was found to consist of 27 of phosphoric acid, 31 of oxide of iron, and 42 of manganese. And iron mineralized by phosphoric acid alone, has also been discovered to be a natural production, forming a mineral of a deep blue colour, in small plates adhering slightly, the surface of which is brilliant; they are translucent, but some, apparently from the loss of water they contain, are opaque. The specific gravity is 2.6.

Iron mineralized by arsénic acid, forms an ore, formerly regarded as an arseniate of copper. It occurs massive, but generally crystallized in small cubes, smooth, and highly shining, the lustre being adamantine; the colour is a dark green, sometimes with a brown or yellowish tinge. The crystals are translucent. The fracture is imperfect foliated; the specific gravity 3000. Analysed by Chenevix, this species was found to consist of 31 arsénic acid, 45.5 oxide of iron, 9 oxide of copper, 4 silex, and 16.5 of water. The copper he regards as accidental, not essential to the composition. Another was discovered, however, in which it was more constant, and in larger proportion, the proportions being 33.5 arsénic acid, 27.5 oxide of iron, 22.5 oxide of copper, 3 of silex, and 12 of water. This species occurs in minute crystals, of a faint sky-blue colour; perfectly transparent, and of very high lustre, and generally grouped irregularly, sometimes united so as to assume a mammillary form.

Sulphate of Iron sometimes occurs in tuberose or stalactitic masses; sometimes in capillary crystals, in imperfect rhombs, or in octaedrons; of a green colour, easily recognised by its solubility in water, its astringent taste, and the usual chemical tests of the salts of iron.

Iron, in combination with sulphur, forms a well-defined species, that known under the name of Pyrites. It occurs massive, disseminated, and frequently crystallized; the forms of its crystals are various, but the most common is the cube regular or modified by truncation of the angles or edges, or acumination of three planes on the angles. Its colour is brass yellow, and the lustre is always fully metallic; it is opaque. The fracture is uneven. It is brittle; its hardness is such as to strike fire with steel; its specific gravity is from 4.6 to 4.8. By friction it exhales a sulphureous smell. This odour is strong when it is heated before the blowpipe; it gives also a blue flame. Various analyses of it have been given; according to those executed by Hatchet, it consists of 52 of sulphur, with 48 of iron.

Besides this Common Pyrites, there are some others, varieties of the species, differing principally in structure or form. The Striated or Radiated Pyrites presents a striated fracture, the striæ being generally diverging. Capillary Pyrites occurs in delicate capillary crystals, grouped, parallel, diverging, or interwoven, slightly flexible, having a metallic lustre, and a colour passing from yellow to steel-grey. Hepatic Pyrites is so named from the liver-brown colour which it assumes from exposure to the air. It occurs massive, of various imitative forms, and crystallized in six-sided prisms, or six-sided pyramids; has less lustre than the others, and is more subject to decomposition.

Magnetic Pyrites, distinguished, as the name implies, by its magnetic quality, has been considered as forming a distinct species. Its colour is deeper, being intermediate between brass-yellow and copper-red, and approaching to brown, often tarnished; its lustre is inferior, but is still metallic. It occurs only massive or disseminated. Its fracture is compact; it is hard and brittle; its specific gravity is 4.5. From Mr Hatchet's analysis of it, it differs from the other iron pyrites, in containing a larger proportion of metal, the proportions of its constituent parts being 36.5 of sulphur, and 63.5 of iron.

There has been much difference of opinion among chemists, with regard to the state of the metal in iron pyrites, whether it is oxidized or not. Vauquelin affirmed, in conformity to an opinion that had been before maintained, that the iron in pyrites is oxidized nearly to the point at which it is easily soluble in acids. Proust, on the contrary, asserts, that in pyrites the iron is entirely in the metallic state: when subjected to distillation, sulphur only was afforded; and the residual matter, he inferred from its resemblance to the artificial sulphuret, did not contain oxygen. The opinion, that the iron in pyrites is in its metallic state, is confirmed by the result of Mr Hatchet's analyses.

SECT. VII.—*Of Ores of Lead.*

LEAD occurs principally mineralized by different acids, and by sulphur.

Carbonate of Lead, the White Lead Ore of mineralogists, is presented under different forms,—earthy, indurated, and crystallized. In the last state, it appears under the forms of the hexaedral prism, the tetraedral prism, the double hexaedral pyramid, the four and the six sided table; and, in acicular crystals, aggregated, and intersecting each other. The surface of the crystals is highly shining, the lustre being adamantine; the colour generally white, sometimes grey, yellowish, or brown; they are transparent, or translucent; are brittle and soft, so as to be easily scratched by the knife. The specific gravity is from 6 to 7. When massive, it has less lustre and transparency. Urged by the flame of the blowpipe, it decrepitates, becomes yellow or red, and melts into a metallic globule. It effervesces with acids, and in diluted nitric acid is completely dissolved. Its composition varies with regard to the proportions of its constituent parts; and it often contains variable quantities of oxide of iron, argil, silex, and lime. A specimen of it, pure, was found by Klaproth to be composed of 77 of lead, 5 of oxygen, 16 of carbonic acid, and 2 of water.

Earthy Lead Ore, which occurs friable or indurated, of a grey colour, of various shades and intermixtures, without lustre or transparency, appears to be a mixture of carbonate of lead with various earthy matters. When associated with an ochrey earth, so as to assume a red colour, it has been named Native Minium. Black Lead Ore appears to be carbonate of lead, altered probably by the action of sulphur, or by intermixture with it, especially as it is found generally incrusting the native sulphuret, and is itself incrusted by the carbonate. A lead ore, which occurs crystallized in cubes similar in appearance to carbonate of lead, but being softer, and having less-specific gravity, was found by Chenevix to contain both carbonic and muriatic acid.

Lead occurs mineralized by sulphuric acid. This ore is always crystallized; the form of the crystals being the octaedron, modified by truncation or bevelment. Its colour is white, with shades of grey; the crystals are transparent, or semi-transparent; their lustre shining and adamantine; the fracture compact; the specific gravity 6.300. It does not effervesce with acids, and is not soluble in nitric acid. According to Klaproth's analysis, it consists of oxide of lead 71, sulphuric acid 24.8, water 2, oxide of iron 1.

Native Phosphate of Lead is a common ore. Its usual colour is green, of various shades; but it passes through yellowish-green into pure yellow. It occurs in general in an incrustation, often mammillary or botryoidal, composed of minute crystals, more or less aggregated, the form of which is the hexaedral prism, truncated or acuminated, and the hexaedral pyramid. They have a waxy lustre, and are translucent; the fracture is uneven; it is brittle and soft. The specific gravity is from 6.2 to 6.9. It does not decrepitate before the blowpipe, but becomes white, and melts easily into a globule of a grey colour, without the lead being reduced. It does not effervesce with nitric acid, but is dissolved by it. It was found by Klaproth to consist of oxide of lead, in various specimens, from 78 to 80, phosphoric acid 18 or 19, muriatic acid 1.5 or 1.7, and a minute trace of oxide of iron. A variety of this species, named Brown Lead Ore, occurs massive, and crystallized in hexaedral prisms, having a waxy lustre, and opaque: it has been found by Klaproth to consist of oxide of lead 78.58, phosphoric acid 19.73, muriatic acid 1.65.

Fourcroy has given the analysis of a lead ore, which occurs in mammillary masses of a yellowish-green colour, containing both phosphoric and arsénic acid, with a little oxide of iron. Lead, too, occurs mineralized by arsénic acid alone. Its colour is green, which passes to yellow; it occurs in acicular or capillary crystals, and also massive. Another variety of native arseniate of lead, with an intermixture of iron, occurs in uniform masses of a rough surface and yellow colour, opaque and dull. These are all distinguished by the strong arsenical odour they give when heated on charcoal by the blowpipe.

Yellow Lead Ore is a species, in which the lead is mineralized by a metallic acid,—the Molybdic Acid. It occurs massive, more commonly in small crystals, the forms of which are rectangular tables of four or of eight sides bevelled, the cube, octaedron, and double eight-sided pyramid. Its colour is wax-yellow, and its lustre waxy; it is translucent, is soft, and easily broken. It decrepitates before the blowpipe, and melts into a globule of a grey colour, in which are disseminated particles of metallic lead; is insoluble in nitric acid. It consists of oxide of lead 58.40, molybdic acid 38, oxide of iron 2.08, and silex 0.28.

Chromate of lead may be noticed under the ores of chrome.

Lead, mineralized by sulphur, forms the most abundant ore of the metal, that named Galena. It occurs massive, disseminated, incrusting, in corroded or reticulated masses, in grains, and crystallized. The forms of its crystals are the cube, the octaedron, the tetraedral prism, the hexaedral prism, and the three-sided table, all perfect or modified by truncation, acumination, or bevelment. Its colour is bluish or lead-grey, sometimes inclining to black, and sometimes iridescent on the surface. Its lustre is splendent and completely metallic; it is perfectly opaque; its fracture is distinctly foliated, in one variety compact; its fragments of a cubical form: it is soft, so as to be easily scratched; it is also easily frangible; its specific gravity is from 7 to 7.7. It decrepitates before the flame of the blowpipe, melts, exhales a sulphureous odour, and affords a globule of lead. The proportions of lead and sulphur vary considerably; that of the lead is from 50 to 83, of the sulphur from 10 to 25. It always contains too a small quantity of silver; and frequently iron, silex, and lime.

SECT. VIII.—*Of Ores of Tin.*

TIN occurs in nature principally in the state of oxide, and in smaller quantity in that of sulphuret.

Native oxide of tin, or Tinstone, occurs massive, disseminated, and frequently crystallized. The forms of its crystals are numerous, in general complicated and imperfectly marked. Its usual colour is brown, of various shades. Its lustre is shining, and, externally in the crystals, is highly splendent; when of a dark colour, it is opaque; when of a lighter shade, translucent, or semi-transparent; its fracture is uneven; it is hard and brittle; its specific gravity is from 6.3 to 6.9. It decrepitates before the blowpipe, and, when heated on charcoal, is reduced. The proportions of its parts vary little. A specimen analysed by Klaproth, gave 77.5 of tin, 0.25 of iron, 21.5 of oxygen, and 0.75 of silex.

Wood Tin Ore, being an oxide of tin, may probably be regarded as a sub-species; though, as Klaproth discovered in it likewise iron and arsenic, it may perhaps form a species. It is found only in small rolled pieces or fragments, and has a distinctly fibrous fracture, whence its name has been derived. Its colour is brown; its lustre glistening; it is opaque, hard, brittle, and has a specific gravity of 6.456. It is not reduced before the blowpipe.

Tin mineralized by sulphur, with copper and a little iron, forms Tin Pyrites. It occurs massive or disseminated; its colour is steel-grey, passing into yellowish-grey; its lustre is metallic and shining, or glistening; it is opaque; its fracture is uneven; it is semi-hard, brittle, and has a specific gravity of 4.350. It is composed of 25 of sulphur, 34 of tin, 36 of copper, and two of iron.

SECT. IX.—*Of Ores of Zinc.*

ZINC is mineralized by oxygen, carbonic acid, sulphuric acid, and sulphur.

Its most abundant ore, Calamine, occurs earthy, or without much induration, sometimes more highly indurated, of a compact or striated texture, forming different varieties. It is massive, often cellular or corroded, or botryoidal, sometimes in minute crystals, forming a drusy incrustation. Its colour is white, but with various shades of yellow; it is dull, translucent; the crystals are nearly semi-transparent; the earthy is opaque. Its specific gravity is from 3.5 to 4. It has the property of becoming electric by heat; when heated before the blowpipe, it becomes white, but is not reduced. Some varieties effer-

Oxide of nickel occurs generally as an incrustation, sometimes disseminated, of a friable texture and earthy appearance; of an apple-green colour, without lustre. Its solution in acids is of a green colour. It occurs generally with kupfer-nickel, or with certain cobalt ores.

SECT. XI.—*Of the Ores of Cobalt.*

THE ores of cobalt are distinguished by giving to borax, when fused with it by the blowpipe, a blue colour, and forming, when dissolved in nitric acid, a solution which becomes green from heat.

White Cobalt Ore is an alloy of cobalt and arsenic, with a little sulphur, and in some specimens a little iron, the two latter being probably accidental. Its colour is tin-white, liable to tarnish, and thus to assume a grey or reddish tinge; its lustre is weakly shining and metallic. It occurs massive and disseminated, of various imitative shapes, and crystallized in cubes, and in octaedrons; the fracture is uneven; it is hard and brittle. Before the blowpipe it melts easily, and gives out an arsenical smoke and odour; it forms a metallic globule, and gives to borax a blue colour. To this species probably belongs the Shining Cobalt Ore, or Cobalt Glance: the colour, lustre, fracture, forms of crystallization, and the chemical characters, being the same, and the differences trivial and accidental.

Grey Cobalt Ore appears to be an alloy of cobalt with arsenic and iron; sometimes with small portions of nickel and bismuth. Its colour is light grey, but liable to tarnish; its lustre weakly shining and metallic. It occurs massive or disseminated; its fracture is even; it is semihard, passing into hard, brittle; and has a specific gravity of from 5.5 to 7.7. Exposed to the flame of the blowpipe, it gives an arsenical odour and smoke; to borax it gives a blue colour.

Native Oxide of Cobalt occurs in a loose form, or of various degrees of induration, but always dull, and earthy in its fracture, soft, and easily broken. It is also of different colours, from the intermixture of oxide of iron, and perhaps other metallic oxides; whence varieties, which have been regarded as the Black, Brown, and Yellow Cobalt Ochres. These all give a blue colour to glass or to borax when fused with it, and sometimes exhale an arsenical odour.

The Peach Bloom Cobalt Ore derives its name from its colour, which is a beautiful red, similar to that of the peach blossom, passing however into other shades of red, and from decomposition into other colours. It occurs massive, disseminated, and in minute crystals. One variety has an earthy fracture, without lustre, and occurs generally as an incrustation: before the blowpipe both varieties lose their colour, become grey, and give a weak arsenical odour; borax receives a rich blue colour. This species has not been accurately analysed, but it is considered as an arseniate of cobalt.

SECT. XII.—*Of Ores of Manganese.*

THE principal ore of manganese is the black oxide. There is another, the Red Ore, the nature of which does not appear to be well determined.

The Native Oxide occurs massive, or in crystals of the form of rhomboidal tetraedral prisms, or in one variety of rhombs. Its usual colour is steel-grey, inclining to brown or black, and varying in its lustre: when crystallized, the surface of the crystals is generally shining; when amorphous, and especially when the fracture is earthy, it is more dull. Its texture is radiated, foliated, compact, or earthy. The specific gravity varies from 3.5 to 4.7. All the varieties have the same chemical characters. They are not melted by the blowpipe, but assume a brown colour. To borax they communicate by fusion a violet-blue colour. With sulphuric acid they yield oxygen gas, on the application of a moderate heat, and muriatic acid they convert into oxymuriatic acid. The radiated variety appears to be a pure oxide, composed, according to Vauquelin's analysis, in one specimen, of 92.75 of oxide of manganese, and 7 of water; in another, of 99.25 of oxide, with 0.25 of water. But there are also frequently present oxide of iron, carbonate of lime, silex, and barytes. The earthy variety contains the largest proportion of oxide of iron; and what has been named Black Wad, which occurs as an earthy incrustation, consists of 43 of oxide of manganese, and 43 of oxide of iron.

Oxide of manganese, probably in a less high state of oxidizement, combined with carbonic acid, has been considered as the basis of what is named Red Manganese Ore; though some have considered the carbonic acid as not essential, and have supposed this ore to be a compound of oxide of manganese with silex. Its colour is rose-red, more or less pale, passing, from exposure to the air and light, to light yellow, or even to white. It has little lustre; occurs massive and disseminated; its specific gravity is 3.233. Before the flame of the blowpipe it does not melt, but acquires a dark-grey colour: to borax it gives, by fusion, a violet tinge.

SECT. XIII.—*Of Ores of Arsenic.*

ARSENIC is found native, pure, or alloyed with other metals, and combined with a little sulphur; and also mineralized by sulphur, by oxygen, and in the state of acid with lime.

Native arsenic is of a white colour, with a slight shade of grey, with metallic lustre; but it tarnishes very quickly on exposure to the air, changing its colour, and losing its lustre. It occurs massive and disseminated; its fracture is uneven; it is semi-hard, very brittle, and has a specific gravity of 5.6 or 5.7. It generally contains a portion of iron, with sometimes a little silver or gold.

Arsenic alloyed with a larger quantity of iron, and with a little sulphur, constitutes the species named Arsenical

Pyrites or Mispickel. Its colour is silver-white, but it quickly tarnishes, and becomes yellow and iridescent; the lustre of its fresh fracture is shining and metallic. It occurs massive, disseminated, and often crystallized; the forms of its crystals being the tetraedral prism, and the octaedron very acute. Its fracture is uneven; it is hard and brittle; has a specific gravity of from 5.7 to 6.5. It contains very little sulphur, and, according to Bergman, from a half to two-thirds of its weight of iron.

Argentiferous Arsenical Pyrites differs not much from the preceding species: its colour is silver-white, with a yellow tarnish, its lustre metallic: with arsenic and iron it contains a portion of silver, which varies from 1 to 10 hundredth parts.

Arsenic, mineralized by sulphur, forms two ores, named Orpiment and Realgar. Realgar is of a red colour, inclining to scarlet, sometimes to orange. It occurs massive, disseminated, and crystallized in oblique tetraedral or hexaedral prisms, generally small, and translucent, or semitransparent, with a shining lustre. It exhales before the blowpipe a white arsenical smoke, with an arsenical and sulphurous odour, and gives a blue flame. It consists of arsenic and sulphur, in the proportions of 80 of the former, and 20 of the latter. Orpiment is of a yellow colour, with a highly shining lustre, is translucent, or semi-transparent when in thin leaves. It occurs massive, and in very minute crystals. Its fracture is distinctly foliated; it is soft, capable of being cut, and somewhat flexible: it exhibits the same appearances before the blowpipe as the red sulphuret. It has been supposed to differ from the red, in containing a much larger proportion of sulphur. Others have supposed, that in both the arsenic may be oxidized, and that in the yellow the degree of oxidizement is greater than in the red. Thenard has lately inferred, that neither of them contains oxygen; they are both sulphurets, the realgar containing the largest proportion of arsenic.

Native oxide of arsenic occurs in the form of an incrustation on other ores, friable or little indurated, sometimes botryoidal, and even in minute crystals. Its colour is white, with shades of yellow or grey, dull and opaque; when crystallized, translucent; its taste is acrid, and it is soluble in water.

Lastly, arsenic has been discovered in the state of acid united with lime, forming the ore named Pharmacolite. This occurs as an incrustation, botryoidal, or in capillary crystals, of a white colour, with sometimes a shade of red, translucent on the edges, and with a silky lustre; its fracture is striated or fibrous; it is soft, so as to soil, and light, the specific gravity being 2.5 or 2.6. It dissolves in nitric acid without effervescence, and gives the arsenical odour by the blowpipe. It contains 23 of lime, 46.5 arsénic acid, 0.5 oxide of cobalt, 6 argil and silex, 22.5 water.

SECT. XIV.—*Of Ores of Bismuth.*

BISMUTH occurs native, mineralized by oxygen, and by sulphur.

Native bismuth has nearly the properties of the pure metal. Its colour is white, verging to red, and often tarnished, with metallic lustre; its fracture is foliated. It occurs massive, disseminated, sometimes crystallized, its crystals being four-sided tables, and cubes, generally small and indistinct. It melts even in the flame of a candle. It dissolves in nitric acid, and its solution is decomposed by the affusion of water.

Oxide of bismuth occurs as an incrustation of a yellowish-grey colour, earthy, or when indurated, having an uneven or foliated fracture; dull when earthy, shining when foliated, opaque and soft.

Sulphuretted bismuth occurs massive, disseminated, and in capillary crystals, of a light green colour, and shining lustre. It melts in the flame of a candle, and when heated, exhales sulphurous fumes.

SECT. XV.—*Of Ores of Antimony.*

THIS metal is found native, combined with oxygen and muriatic acid, and mineralized by sulphur.

Native antimony is of very rare occurrence. It has the usual characters of the metal, and contains a very minute portion of silver and iron.

Antimonial Ochre, as it has been named, occurs as an earthy-like incrustation, of a straw-yellow colour, on the surface of the sulphuret, and has been supposed to be an oxide. Another ore, which appears to be an oxide of more uniform composition, is that named White Antimonial Ore, occurring in acicular crystals, grouped and divergent, so as to form a stellular appearance, and likewise in tables and in cubes, of a snow-white colour, silky lustre, translucent and soft. Lampadius had assigned muriatic acid as a constituent principle of it, but both Vauquelin and Klaproth have found it to be an oxide without any traces of this acid, its composition, as stated by the former chemist, being 84 of antimony, 3 of oxides of antimony and iron, and 8 of silex.

The sulphuret is the principal antimonial ore. It occurs massive, disseminated, or crystallized, its crystals being acicular or prismatic, and often aggregated. Its colour is lead-grey, frequently tarnished or iridescent; its lustre is shining and metallic. Its fracture is commonly striated or radiated; in one variety it is foliated, and in another small-grained uneven. It melts easily before the blowpipe, and exhales fumes of sulphur and oxide of antimony. It consists of 74 of antimony, and 26 of sulphur. Plumose Grey Antimonial Ore is a variety of this, or perhaps a distinct species, containing, with sulphuret of antimony, portions of arsenic and iron, and sometimes a little silver. It occurs generally in capillary crystals.

Red Antimonial Ore is probably a sulphuretted oxide of antimony, its composition, as determined by Klaproth, being 67.5 of antimony, 10.8 of oxygen, and 19.7 of sulphur. It occurs in capillary crystals of a deep red colour, opaque, and shining. It melts before the blowpipe, and exhales in vapour.

SECT. XVI.—*Of Ores of Tellurium.*

THIS metal occurs chiefly alloyed with other metals.

In its purest state it forms an alloy formerly named Aurum Paradoxicum, the proportion of tellurium being 90 in 100 parts, with a portion of iron and gold varying from 1 to 9 parts. It is massive, disseminated, or in small crystals of a white colour, and shining metallic lustre, having a foliated fracture, and a specific gravity from 5.7 to 6.1. It melts before the blowpipe, gives a white smoke, and is oxidized.

In the graphic gold ore, the portion of gold is larger, and silver is associated with it, the proportions, as determined by Klaproth, being 69 of tellurium, 30 of gold, and 10 of silver. It is usually crystallized in minute prisms, superficially aggregated on quartz in a form giving the appearance of letters, whence the name Graphic is applied to it. Its colour is steel-grey, its lustre metallic, but liable to tarnish, its fracture uneven, its specific gravity 5.7. It burns before the blowpipe with a green flame, and is volatilized.

In the white or yellow sylvanite, there is present a portion of lead, with tellurium, gold, and silver. Its colour is silver-white, inclining to yellow; its lustre metallic; its fracture foliated; its specific gravity 10.6. It occurs disseminated, or in minute crystals.

In the black tellurium ore, a number of metals are combined with a little sulphur, the composition, as stated by Klaproth, being tellurium 82, lead 54, gold 9, copper 1.3, silver 0.5, and sulphur 3. It occurs massive, and crystallized in six-sided tables; its colour is blackish-grey; its lustre metallic; its fracture foliated; its specific gravity 8.9. It melts before the blowpipe, and is partly volatilized.

SECT. XVII.—*Of Ores of Chrome.*

CHROME is found in the mineral kingdom in the state of acid combined with oxide of lead, and in that of oxide or acid united with oxide of iron, forming two species.

Chromate of Lead, the red lead ore of mineralogists, is usually crystallized in rhomboidal four-sided prisms. Its colour is aurora red, is lustre shining and adamantine; it is translucent; its specific gravity is 6. It consists of 64 of oxide of lead, and 36 of chromic acid.

The second species occurs massive, is of a dark-brown colour, dull, and opaque; hard, difficult to break, and has an uneven fracture; its specific gravity is 4. It consists of oxide of chrome 55.5, oxide of iron 33, argil 6, silex 2, and 3.5 of loss. It appears to be more extensively diffused than the other.

Sect. XVIII.—*Of Ores of Molybdena.*

There is only one ore of this metal,—the sulphuret. It occurs massive, disseminated, and sometimes crystallized in hexaedral prisms or tables. Its colour is lead-grey, its lustre is shining and metallic, its fracture is foliated; and it is easily split; it is soft, so as to soil; it feels unctuous. Its specific gravity is from 4 to 4.7. It consists, according to Klaproth and Bucholz, of 60 of molybdena, and 40 of sulphur.

Sect. XIX.—*Of Ores of Tungsten.*

The mineral named Tungsten consists of the oxide of the metal to which this name is now appropriated, with lime, the proportions, according to D'Elhuyart, being 68 of the former with 30 of the latter. It occurs massive, disseminated, and in octaedral crystals. Its colour is yellowish or greyish white; its lustre shining and vitreous; it is translucent or semi-transparent, is soft, has a foliated fracture, and a specific gravity from 5 to 6. Digested in nitric or muriatic acid, it affords a yellow powder, which is the oxide of tungsten.

The other species of this genus is the mineral named Wolfram. It occurs massive and crystallized in broad hexaedral prisms, or four-sided tables. Its colour is black, its lustre weakly shining; it is opaque; its fracture is distinctly foliated; its specific gravity is from 6.8 to 7.1. It consists of oxide of tungsten, with oxides of iron and manganese, the proportions of which differ much in different specimens.

SECT. XX.—*Of Ores of Titanium.*

UNDER this genus are placed several species, differing much in their external characters.

Rutile, Titanite, or Red Shorl, is nearly a pure oxide of titanium. It occurs crystallized in prisms, frequently capillary, and penetrating quartz; its colour is red or reddish brown; its lustre shining; it is slightly translucent; it is hard and brittle, and has a foliated fracture; its specific gravity is 4.1. Rutilite, which occurs in rhomboidal four-sided prisms of a reddish-brown colour, appears to be a variety of this, containing, with oxide of titanium, silex and lime.

Oisanite, octahedrite, or blue shorl, is regarded by Vauquelin as a pure oxide of titanium, differing from rutile in being free from iron. It is crystallized in acute octohedrons; its colour is blue, passing sometimes into brown; its lustre is shining and adamantine; it is translucent or semi-transparent; its fracture is foliated; its specific gravity 3.8.

Menachanite occurs in small irregular grains or sand, of a greyish-black colour, opaque, with semi-metallic lustre, having a specific gravity of 4.4, and weakly attracted by the magnet. It consists of oxide of iron 51, oxide of titanium 45.25, oxide of manganese 0.25, and silex 3.5. Nigrine is perhaps a variety of this; it is also in angular grains of a brownish-black colour, with little lustre, and opaque; its specific gravity is 4.5; it is not attracted by the magnet; it consists of 84 of oxide of titanium, 14 of oxide of iron, and 2 of oxide of manganese. Iserine occurs likewise in angular grains, of a black colour and weak lustre, and opaque, having a specific gravity of 4.5. It consists of oxide of titanium 59.1, oxide of iron 30.1, and oxide of uranium 10.2.

SECT. XXI.—*Of Ores of Uranium.*

THE mineral named Pechblende is the ore in which this metal was first discovered. It is generally massive, of a black colour, with an internal lustre, shining, and resinous; opaque, brittle, and soft; having a specific gravity of 7.5. It consists of 86.5 of oxide of uranium, with 6 of sulphuret of lead, 5 of silex, and 2.5 of oxide of iron.

Green Mica, or Micaceous Uranitic Ore, is oxide of uranium nearly pure, or mixed only with a little copper. It occurs in thin leaves, or crystallized in minute four-sided tables; its colour is green; its lustre shining, with little transparency; its fracture is foliated; and it is soft and easily broken.

Uranitic ochre occurs usually as an incrustation or efflorescence, of a straw-yellow colour, without lustre, opaque, soft, and friable. It is oxide of uranium nearly pure, containing sometimes a little oxide of iron.

Sect. XXII.—*Of Ores of Tantalum.*

The alloy of this metal with iron and manganese, forms the mineral named Tantalite. It occurs in imperfect octaedral crystals of a black colour, with an internal metallic lustre; hard so as to give sparks with steel, and having a specific gravity of 7.9. Ittrotantalite is composed of tantalum, with iron and a portion of the earth ittria; it is in small imbedded masses of a black colour, with metallic lustre; having a granulated fracture, and a specific gravity of 5.1. Columbium being the same as tantalum, the mineral in which Mr Hatchet discovered that metal must be regarded as belonging to this genus. Dr Wollaston has remarked, that in external appearance it is perfectly similar to tantalite; and its composition is the same.

Sect. XXIII.—*Of Ores of Cerium.*

There is only one ore belonging to this genus, Cerite, or, as it was first named, False Tungsten. It occurs massive or disseminated; of a flesh-red colour, semi-transparent; and having, in the fresh fracture, considerable lustre; it is so hard as to strike fire with steel; and has a specific gravity of from 4.7 to 4.9. It consists of oxide of cerium 50, oxide of iron 22, silex 23, and 5.5 of carbonate of lime.

CHAP. IV.

OF INFLAMMABLE MINERALS.

Under this order are placed those minerals not metallic, which have the property of inflammability. They admit of being arranged under three genera, resting on chemical distinctions. Sulphur constitutes one genus. Under a second may be placed those composed of carbon principally,—the Diamond, Plumbago, and Coal. To a third I have referred the Bitumens. These consist chiefly of carbon and hydrogen, forming a series in which these principles are combined in different proportions, the hydrogen being usually predominant. Under this genus may probably be placed amber and honey-stone.

Sect. I.—*Of Native Sulphur.*

Sulphur occurs in the mineral kingdom principally as a volcanic product, though it is also found not of volcanic origin. It is usually pure, of its characteristic yellow colour, semi-transparent, or sometimes transparent, with shining lustre; it occurs massive, disseminated, or crystallized, the form of its crystals being the octohedron or dodecaedron under various modifications. It also occurs corroded, vesicular, in masses, and as a light sublimate. Its other physical and its chemical properties are those of pure sulphur.

Sect. II.—*Of Carbonaceous Minerals.*

Of these the Diamond is the purest. From its external characters, it has been placed among the earthy fossils; but as it is inflammable, and its nature perfectly ascertained, it must, in conformity to its chemical relations, be placed under the present genus, though differing widely from the other substances with which it is associated.

The Diamond is not met with in its original situation, but in the beds of streams, or in a loose ferruginous sand beneath the soil, either in perfect crystals, or in fragments often encrusted with a hard coating. The usual forms are the octohedron and dodecaedron variously modified, and generally imperfect. It is colourless, or tinged of various colours; it is generally transparent, and has the property of single refraction; its fracture is lamellated, and it can be split by striking it in the direction of the plates. Its hardness is such that it is not impressed by steel. Its specific gravity is from 3500 to 3600.

Plumbago, or **Graphite**, is a carburet of iron, the proportion of the metal, in different specimens, being very various. Graphite occurs massive, or disseminated; its colour is black, or dark steel-grey; its lustre weakly shining and metallic; it is opaque; its fracture is compact, foliated, or slaty; it is soft, soils the fingers, and feels unctuous; its specific gravity is from 2.1 to 2.6. It burns with great difficulty, and consumes slowly, leaving oxide of iron as a residuum, frequently mixed with argil and silex.

Coal consists essentially of carbonaceous matter, and in one variety, the blind coal, this is nearly pure; but in the greater number of the varieties of coal, there is associated with this a soft bituminous matter, which communicates to them some peculiar properties. Those which contain much bitumen are highly inflammable, take fire readily, and burn with a bright flame; those in which the proportion of bitumen is less, and in which the carbon predominates, burn less vividly; they require a higher heat to kindle them, and burn without flame, or only with a red glow.

Numerous varieties of coal exist, deriving their distinctions partly from their state of aggregation, but principally from the proportions of their bitumen and carbon. The series may be briefly described, as they are connected, on the one hand, with vegetable matter, and on the other, with carbon not of vegetable origin.

Blind Coal, the Anthracite of mineralogists, the Glance Coal of Werner, consists almost entirely of carbon, with a little earthy matter and iron, and forms the connection of coal with plumbago. It burns with difficulty, without flame, without exhaling any bituminous odour, and without softening or caking; its colour is usually black; its lustre shining, and nearly metallic; its fracture slaty; its hardness such as to yield easily to the knife; it is brittle, and has a specific gravity of about 1.5. It occurs often in primitive rocks, or in those of transition in imbedded masses, in beds and veins; and there appears no reason to infer that it is of vegetable origin.

Black Coal, as it is named by Werner, is the common coal, of which there are several varieties. That which is of a slaty fracture is the variety most abundant in this country; its principal fracture is slaty, the cross fracture small grained uneven; its colour is black, frequently with a shade of grey; its lustre resinous; it is soft, and has a specific gravity of about 1.25. It softens, cakes, and burns brightly, and leaves, when entirely burnt, a small residuum of ashes. It contains a considerable proportion of bitumen, varying, however, so much as from 24 to 40, with from 53 to 70 of carbon, and 2 or 3 of earthy matter. Foliated coal approaches to the slaty, being distinguished by its fracture and its greater lustre; it is softer, and appears to contain more bitumen. Columnar coal is so named from occurring in columnar distinct concretions, and is more rare. Cannel coal is distinguished by its smooth conchoidal fracture; it has a resinous lustre and black colour, and burns at first with a clear light, which, however, soon ceases. It contains about 75 of carbon, with 22 of bitumen, and 3 of foreign matter. Pitch coal has also a smooth conchoidal fracture; from the closeness of its texture it takes a polish, and forms what is named Jet.

Brown Coal occurs massive, having an imperfect conchoidal fracture, sometimes fibrous and woody, soft and light; it burns with a blue flame, and gives a smell like bituminous wood; it occurs with some of the following varieties, in alluvial land: it contains little bitumen. Connected with this is what is named Earthy Bituminous Wood, or Earthy Coal, which is found of a loose consistence, nearly earthy, dull, of a blackish-brown colour, light and soft. The last of the series, or that most evidently of vegetable origin, is Bituminous Wood. The ligneous texture is very distinctly marked, and even the external shape of the branches and stems of trees, and the annual rings of the wood, are distinctly preserved, so as to resemble wood imperfectly charred. Its colour is brown, of different shades; it is opaque, with little lustre; has little density or hardness, and is so light as nearly to float on water. It burns with a clear flame, and with a bituminous odour, and leaves a small quantity of white ashes, similar to those from wood.

Coal, excluding the anthracite or blind coal, is evidently of vegetable origin. We trace in it the gradation from bituminated wood; we often discover in its varieties the ligneous structure, and even the remains of plants; and its chemical composition agrees with that of vegetable matter. It is difficult, however, to determine in what manner it has been formed, or by what operations the vegetable matter from which it is originated, has been so far modified as to have assumed the properties under which it exists. The discussion of this subject is intimately connected with geological speculation; for the opinion which is adopted must be in conformity to the general theory which is held with regard to the structure of the globe. It is accordingly maintained in one geological system, that it derives its origin from vegetable matter which had been exposed under compression to subterranean heat; while in another it is supposed to have been formed from vegetable matter suffering slow decomposition under water, or at least in a state of humidity, by which its oxygen and hydrogen had been in a great measure withdrawn, and its carbonaceous base left predominant. The merits of either theory must rest on those of the more general systems with which they are connected.

The bituminous part of coal is separated from the carbonaceous part by the application of heat. We perceive this separation in its combustion in a common fire; the coal, when first kindled, swelling and softening, exhaling a kind of bitumen, and burning with smoke and light; while, after a certain period, these appearances cease, and it burns only with a red light. The separation is effected more completely by the application of heat in close vessels; the bitumen is melted out, and there are disengaged a large quantity of ammonia, partly in the state of carbonate with a quantity of empyreumatic oil, and a gas, a variety of oxy-carburetted hydrogen, approaching in its nature to olefiant gas, which burns with a bright flame; the carbonaceous matter is in a great measure left, forming Coak.

This decomposition of coal by heat has been carried on on a large scale, with a view to collect the products; the bituminous matter, or mineral tar, being applied to the uses for which vegetable tar and pitch are employed, and the coaked coal being used in the smelting of metallic ores, and for other purposes. More lately the distillation of coal has been applied to the procuring an elastic fluid, to afford by its combustion artificial light, and has some advantages, particularly of affording a steady, uniform, and easily-regulated light, and of being economical, especially when the process is conducted on a large scale.

SECT. III.—*Of Inflammable Minerals, in which Hydrogen predominates.*

To this genus belong principally the liquid bitumens.

Of these NAPHTHA is the purest. It is very light, of a pale yellow-green colour, transparent, thin and liquid, odoriferous, volatile, and inflammable, and in burning is entirely consumed, emitting a smoke more or less dense. PETROLEUM, or Mineral Tar, is semi-liquid, often of a thicker consistence, tenacious, semi-transparent, of a reddish-brown colour, and fœtid odour. MINERAL PITCH, or Maltha, is solid, but soft, has a degree of tenacity, and a strong bituminous smell. Its colour is black, its lustre highly resinous. It is sometimes elastic, forming what has been named the Elastic Bitumen. ASPHALTUM is the last of the series, and forms the connection with pitch coal. It is of a black colour, and resinous lustre, without transparency; its fracture is conchoidal; it is light, and has a bituminous smell when rubbed or heated. It melts easily, takes fire, and burns without leaving any ashes. Through all these substances there is a perfect gradation; naphtha, by inspissation, becoming petroleum, and this, by the same operation, passing into asphaltum; and even the different specimens of these are frequently found in the same situation. They also agree in their chemical characters, are inflammable, insoluble in water and in alkohol, but combine with fixed and essential oils, and are partially soluble in ether. They are not dissolved by the alkalis, and are decomposed by the more powerful acids.

Amber is usually placed among the bitumens, though it differs considerably in its properties. It is of a yellow colour, pale or deep, with a shining lustre, and a transparency more or less perfect; its fracture is conchoidal; it is brittle, and has a specific gravity of about 1.08. It is inodorous except when heated; when rubbed, it becomes strongly electrical. It occurs in fragments, or sometimes in large masses; it is found in layers of bituminated wood, often also buried in sand on the sea-shore. No satisfactory theory has been given of its origin. It often contains very perfect organic remains,—a proof of its having been once perfectly fluid.

When amber is exposed to heat in close vessels, it softens and swells; and with a portion of empyreumatic oil, a quantity of an acidulous liquor passes over; this is succeeded by a concrete acid, which condenses in flakes or needles, which is obtained from no other substance, and is different from all the other acids. When heated in contact with the air, it inflames, burns with much smoke, and with a strong bituminous smell; and leaves little residue.

Water exerts no action on amber. Alkohol acts on it weakly, acquiring only some degree of colour and tenacity. The alkalis dissolve it, forming a kind of soap. The acids decompose it, changing it into a species of resin, and ultimately into tannin. It is not dissolved either by the expressed or essential oils; but it becomes soluble by being roasted gently. Solutions of this kind are used as varnishes.

The empyreumatic oil obtained from the decomposition of amber by heat is thick, and of a dark colour; by distilling it repeatedly with water, it becomes thinner and of a lighter colour. It still retains a fœtid smell; is volatile and inflammable; insoluble in water, and imperfectly soluble in alkohol. It also combines imperfectly with the alkalis.

The acid obtained by the same decomposition, the Succinic Acid, is possessed of properties which sufficiently distinguish it. When freed from the small portion of oily matter which adheres to it at its first sublimation, it is white, and crystallizes in four-sided rhomboidal plates; its taste is sour, and it reddens infusion of litmus; it is soluble in 24 parts of water at 60, and is also soluble in alkohol. It is volatile and inflammable. Like the other vegetable acids, it has a compound base of carbon and hydrogen.

Succinic acid combines with the alkalis, earths, and metallic oxides, but these combinations present no important results. The succinate of iron is insoluble; hence succinic acid has been employed as a test of this metal, and as a re-agent by which substances may be freed from it, succinate of potash being added to any solution containing iron, and the succinate of iron being precipitated. It is also used to discriminate between magnesia and argil, the succinate of magnesia being soluble, while that of argil is insoluble, and is therefore precipitated.

Mellite, or Honey-stone, has been placed among the bituments, with which, though it differs from them considerably, it has some relations. In its external appearance it has some resemblance to amber: it is of a honey-yellow colour, is more or less transparent; its lustre is intermediate between vitreous and resinous; its surface smooth; its fracture conchoidal; it is brittle, and softer than amber; has a specific gravity of 1.6. It occurs generally crystallized; its crystals being octaedrons, dodecaedrons, or four-sided prisms acuminated by four planes. It becomes weakly electrical from friction. When heated in contact with the air, it becomes white, and burns without becoming sensibly charred, leaving a white matter, which produces a slight effervescence with acids.

This substance is found in the layers of bituminated wood. Its nature was unknown until it was analysed by Klaproth, who found it to consist of a peculiar acid, which has hence received the name of Mellitic Acid, united with argil.

The acid may be extracted merely by the action of water, and by evaporation can be obtained in a mass, which, when subjected to the action of alkohol, to separate a portion of earthy matter, may be crystallized. Its crystals are prisms, have a yellowish tinge, and a slight acid taste, accompanied with bitterness. It is sparingly soluble in water. Exposed to heat it swells up, emits a dense smoke, is charred, and leaves a light coal, and, from the products of its decomposition, is evidently analogous in constitution to the vegetable acids.

Mellitic acid combines with the different salifiable bases, but these combinations have been only imperfectly examined, and present no important results. They are somewhat similar to those of oxalic acid, and to this acid, too, the mellitic acid has a considerable resemblance.

In concluding the history of mineral substances, it might be supposed necessary to take a view of the theories which have been advanced with regard to their formation. The subject, however, involves details not strictly chemical, and cannot be considered as purely elementary. The opinions which are maintained with regard to it are so discordant, and our knowledge of the facts so imperfect, that a brief statement, such as is consistent with the limits of this work, would scarcely be satisfactory. I may therefore refer to the view which I have given of it in my System of Chemistry, or to the more ample discussion of the controversy, in the Comparative View of the Huttonian and Neptunian Systems of Geology.

CHAP. V.

OF MINERAL WATERS.

Mineral waters, containing very various ingredients, cannot properly be placed under any of the established classes of chemical agents; but they may be considered after the metallic and earthy fossils, as it is from these that they derive in general their peculiar properties. Though all waters, that which descends in rain excepted, may be styled Mineral, as they contain more or less of saline and earthy matter, yet the term is restricted to those in which the quantity is such as gives the water taste or smell, renders it capable of producing peculiar effects on the animal system, or communicates to it distinguishing chemical properties.

The substances found in mineral waters are extremely numerous. The most common are, carbonic acid; sulphuretted hydrogen; carbonates, sulphates, and muriates of soda, lime, and magnesia; and carbonate and sulphate of iron. These are variously intermixed, and the water is classed as acidulous, sulphureous, saline, or chalybeate, according to the ingredients which predominate in it. Substances of more rare occurrence are, sulphurous acid, nitrogen gas, sulphate of argil, muriate of manganese, and siliceous earth.

The first step in the analysis of a mineral water is to ascertain the gaseous substances it contains, as these frequently contribute to hold the solid substances dissolved.

Carbonic acid, when uncombined, or in excess, may be discovered by the pungent acidulous taste of the water, and its sparkling appearance when poured into a glass. They become vapid from exposure to the air, or to a moderate heat, from the escape of the gas. The chemical tests to discover it are infusion of litmus and lime-water; the first receiving from the mineral water containing it an evanescent redness, the second producing a milkiness or precipitation which disappears when an excess of the mineral water is added, the carbonic acid rendering soluble the carbonate of lime, to which the turbid appearance is owing. The transparency is equally restored by dropping into the liquid a little muriatic or nitric acid. By the evanescent redness given to litmus, carbonic acid is distinguished from any other free acid that might be present, and by the transparency being restored by these re-agents, the fallacy is guarded against that might arise from the precipitation of the lime by any sulphate in the water. The quantity of free carbonic acid gas may be ascertained by exposing the water to heat in a retort, collecting the gas disengaged from it in a jar over mercury, and introducing to it a solution of potash, by which the carbonic acid gas is absorbed.

Sulphurous acid gas is very seldom to be looked for; when present, it is discovered by its smell, by giving a permanent red colour to a solution of litmus, and by rendering colourless an infusion of roses. Its quantity is estimated by expelling it, exposing the gas to a solution of potash, and obtaining the sulphite of potash; or by adding to it sulphuretted hydrogen gas as long as any diminution of volume is produced, these two gases, by their mutual action, being converted into water and sulphuric acid, and being therefore entirely condensed.

Nitrogen gas is discovered by remaining unabsorbed when the elastic fluid expelled from a mineral water by heat has been exposed to the action of a solution of potash.

Sulphuretted hydrogen, existing in a water, is discovered by its smell, by the deposition of sulphur from it on exposure to the air, or on the addition of nitrous acid, by blackening silver or mercury immersed in it, and affording a dark-coloured precipitate with acetate of lead. The quantity of it has been estimated by expelling it from the water by the application of heat, but the whole of it cannot thus be expelled; it cannot easily be collected to be measured with accuracy, as it is absorbed by water, and acts on quicksilver. It may be decomposed by the addition of fuming nitrous acid; or, according to Kirwan's method, a quantity of the water is inclosed in a jar with atmospheric air, which is inverted in water: nitrous gas is passed through the water, so as to combine with the oxygen of the atmospheric air: nitrous acid is formed, and this, being absorbed by the water, decomposes the sulphuretted hydrogen; the quantity that has been present may be discovered from the quantity of sulphur precipitated, and collected on a filtre, 30 grains of sulphur being held equivalent to 100 cubic inches of sulphuretted hydrogen gas. When sulphuretted hydrogen and carbonic acid gases exist together in the mineral water, the elastic fluid obtained from the water by heat, is exposed in a tube to nitrous acid, by which the sulphuretted hydrogen is immediately absorbed and decomposed.

After the gaseous substances existing in mineral waters have been ascertained, the solid contents are to be examined.

The mineral acids, when combined with any base, or in excess, are discovered by the water giving a permanent red colour to vegetable infusions; but in this state they are very rarely present.

The neutral and earthy salts are the chief ingredients of mineral waters. We have to ascertain the acids they contain, and the bases with which these are united; and for this purpose it is in general necessary to reduce the volume of the water by evaporation, to render more sensible the operation of the re-agents by which they are detected, taking care only, when the evaporation is executed with this view, not to carry it so far as to give rise to the separation of any of the solid ingredients.

Sulphuric acid, in combination with the alkalis or earths, is detected by muriate of barytes, acetate of lead, and nitrate of mercury, all of these producing an immediate precipitation. The first is at once the most delicate and most accurate, and the others therefore may be regarded as superfluous. Its delicacy is such, that it discovers the most minute quantity of sulphuric acid. The only fallacy to which it is liable, is one easily guarded against, that of affording a precipitate from the presence of alkaline or earthy carbonate; this is obviated by adding, previously to the water, a small quantity of pure nitric or muriatic acid, or by the turbid appearance, after it has been produced, disappearing, if it has arisen from this, on the addition of a few drops of either of the acids.

Muriatic acid is detected by the nitrate of silver; the muriate of silver which is formed being, from its very sparing solubility, instantly precipitated, and giving rise to a bluish turbid appearance. The delicacy of this as a re-agent is great, the most minute quantity of muriatic acid in any state of combination being detected. It is liable to fallacy, however, from a precipitate being likewise produced by it from the presence either of any carbonate or any sulphate. The operation of the former is obviated by the previous addition of a few drops of pure nitric acid, which decomposes the carbonate, and expels the carbonic acid; to avoid the latter, it is necessary to decompose any sulphate, if present, by the addition of nitrate of barytes.

Carbonic acid, in a state of combination with the alkalis or earths, may be discovered by the effervescence produced by the addition of sulphuric acid, and by muriate of barytes forming a precipitate soluble with effervescence in nitric or muriatic acid, the effervescence being in particular apparent when concentration has been produced by evaporation. The alkaline carbonates are distinguished by their power of changing the vegetable colours; the earthy and metallic carbonates, by being precipitated when the water is partly evaporated.

These are the acids usually met with in mineral waters. They are commonly combined with the fixed alkalis, lime, magnesia, or argil, or with oxide of iron.

Lime is *immediately* precipitated from all its combinations by oxalic acid. Some of the mineral acids, however, either decompose this acid, or hold dissolved the precipitate it forms with the lime, and hence, if disengaged by the decomposition itself, may have this effect. This fallacy is in a great measure guarded against by using, not the pure acid, but oxalate of potash; the potash neutralizing the acid disengaged from the lime; oxalic acid produces a precipitate likewise with magnesia, but this takes place very slowly, even when the magnesian salt is in large quantity, while with lime it is immediate. Sulphuric acid is also a test to discover lime; but it is one of much less delicacy.

Ammonia and lime-water are the tests of magnesia, the former precipitating it partially, the latter entirely. In order that the lime may be an accurate test, it is necessary to remove any carbonic acid which may exist in the water, by previously adding nitric acid; and any sulphuric acid, by muriate of barytes. Another source of fallacy more important, arises from argil being precipitated by these tests, as well as magnesia. The nature of the precipitate may be discovered by dissolving it in nitric or muriatic acid, and again precipitating the solution by carbonate of potash. If this dried precipitate be subjected to the action of diluted sulphuric or muriatic acid, it will be immediately dissolved if the earth be magnesia, while, if it be argil, it will dissolve slowly. Another test which discriminates between these earths is boiling the precipitate in a solution of potash; if it be argil, it is dissolved, while magnesia remains undissolved. Succinate of ammonia, too, precipitates argil, but not magnesia. By these tests argil is likewise discovered.

The alkalis, when in a state of combination, cannot be discovered by any striking tests, but their presence is inferred when acids are discovered in a mineral water, which are not free, and which at the same time, from the application of tests, do not appear to be combined with earthy or metallic bases. Soda is the alkali generally present. The peculiar salts which it and potash form with the different acids, serve to distinguish them. With oxalic acid, soda forms a salt sparingly soluble; while potash forms, with the same acid, a salt easily dissolved. With tartaric acid, on the contrary, soda forms a soluble salt; while with potash, an acidulous tartrate is formed, of comparatively sparing solubility. Muriate of platina affords a test still more delicate, giving a precipitate with the salts or potash, but not with those of soda.

Siliceous earth is contained in some waters, not combined, however, with any acid. A portion of alkali, likewise, generally exists in such water; but this is either in the state of carbonate, or in such small quantity that it can scarcely be considered as the solvent of the silex. This earth may be discovered by evaporating the water, and adding to the solid residuum nitric or muriatic acid; the silex will remain undissolved; and its nature may be still more clearly proved by fusing it by the blowpipe, with either of the fixed alkalis.

Of the metals existing in mineral waters, iron is the principal; any other, indeed, is of very rare occurrence, and only in particular situations. It is combined sometimes with sulphuric acid, but much more generally is held dissolved by carbonic acid.

Chalybeate waters, as those impregnated with iron are named, deposite an ochrey sediment on exposure to the air. The iron is discovered by very delicate tests, principally the infusion of galls, and the prussiate of potash, the former striking a purple colour, the other giving rise to a blue precipitate. The latter is liable to fallacy, principally from the iron which exists in its composition, and which is liable to be evolved by an acid, so as to give rise to the blue precipitate. The former is not liable to this or any other important fallacy, and is much more delicate, a deep colour being struck when the iron is present in very small proportion. The colour is liable to be varied by the action of various salts; alkaline and earthy carbonates rendering it violet, neutral alkaline salts deepening the purple tint, and sulphate of lime rendering the precipitate at first whitish, and afterwards black. Carbonate of lime has a singular effect. If the iron be in small quantity, and at a high state of oxidation, the colour does not even appear; while, if it is at a low state of oxidation, the purple tint is even heightened. By applying this test before and after ebullition of the mineral water, we discover whether the oxide of iron has been held dissolved by carbonic acid or sulphuric acid, as if the former has been the solvent, being expelled during the boiling, the oxide is in a great measure precipitated, so that the liquor, after filtration, when cold, either does not suffer the change of colour, or the tint is much less deep. The quantity of oxide may be in some measure determined by its precipitation from exposure to the air and ebullition; or, according to a more recent mode, it may be precipitated by succinate of soda, and the precipitate, calcined at a red heat with a little carbonaceous matter, gives the quantity of oxide of iron.

Besides the methods of discovering the saline compounds in mineral waters by the application of re-agents which indicate their principles, they may, by certain methods, be obtained in their entire state, and their quantities determined.

Evaporation is employed with this view, different substances being successively obtained as the evaporation is carried to a greater or less extent. Thus the carbonates of lime and magnesia are usually first precipitated, afterwards sulphate of lime falls down; if after these precipitations the liquor be drawn off and allowed to cool, the alkaline neutral salts and the sulphate of magnesia crystallize, while muriate of magnesia and muriate of lime, if present, will remain dissolved, forming an uncrystallizable residue.

Alkohol facilitates the analysis by a similar operation. When added to the water brought to a certain state of concentration, it throws down first sulphate of lime, afterwards carbonate of lime and carbonate of magnesia; and if added in larger quantity, or after a renewed evaporation, it either precipitates or causes to crystallize sulphate of magnesia and sulphate of soda, while any muriates remain dissolved. Advantage too is taken of its solvent power, the solid substances being obtained by evaporation to dryness, and their separation being facilitated by the addition of alkohol in successive portions.

By these methods, the quantities of the solid substances contained in a mineral water are determined. These are also frequently inferred by estimation from the precipitates afforded by the usual re-agents. Thus the quantity of sulphuric acid may be ascertained from the weight of the precipitate formed by adding muriate of barytes, the proportion of sulphuric acid which a given weight of this brought to a certain state of desiccation contains, being known. The quantity of muriatic acid may be inferred from the weight of the precipitate formed by adding nitrate of silver; that of carbonic acid, from the weight of the precipitate formed by water of barytes or lime; that of lime from the weight of the oxalate of lime precipitated by oxalate of potash; and, in a similar manner, the weights of other substances that can be precipitated by re-agents in new states of combination may be determined. The method is indeed liable to some fallacy, from the uncertainties which attend the determination of the proportions of compound salts. But it may be combined with the others, and it is only from these combined methods that an accurate analysis can be obtained.

BOOK VIII.

OF VEGETABLE COMPOUNDS.

THE compounds which are the products of the chemical processes carried on in the vegetable, and also in the animal system, have peculiar chemical characters, by which they are distinguished from the compounds which exist native in the mineral kingdom, or which are capable of being artificially formed. Their composition is in general more uniform with regard to the principles of which they are composed, but more complicated with regard to the number of elements existing in simultaneous combination, and much more diversified in the proportions and modes in which these are united. Carbon, hydrogen, and oxygen, are their chief constituent principles, to which are sometimes added, in smaller proportions, nitrogen, sulphur, phosphorus, lime, and iron; and it is from differences in the proportions, and in the modes of combination, that the immense diversities of properties by which these substances are distinguished are derived. These principles, too, are not united in binary compounds, but exist in more complicated states of union; their affinities are therefore more nearly balanced, and of course are more easily subverted. Hence the susceptibility of decomposition, by which the vegetable and animal compounds are distinguished; they are liable to spontaneous change from the mere re-action of their elements, especially when this is favoured by a state of solution, or the presence of humidity; they are, even at common temperatures, acted on by the oxygen of the atmosphere; and at elevated temperatures, their existing composition is entirely subverted. In all the decompositions, too, to which they are liable, their principles are not disengaged in an insulated state; for, having strong mutual affinities, they enter into combination, and form new products. From this circumstance, and from the similarity in composition with regard to the principles of these compounds, the products of their analysis are nearly the same, differing principally, at least, in the proportions in which they are disengaged. It is therefore difficult, from the results of the analysis, to determine the composition with perfect accuracy; and we are in all cases unable to confirm it by synthesis, for we have not the power, by any adjustment, of balancing the affinities of the ultimate principles, or of placing them under circumstances similar to those in which they have been combined; and hence these compounds can never, by direct combination, be artificially formed.

The vegetable compounds are rather more simple in their composition than those formed in the animal system. They consist chiefly of carbon, hydrogen, and oxygen, and more rarely contain nitrogen, sulphur, or phosphorus; hence their composition is rather more permanent, as it depends on a less nice adjustment of affinities; they are at least less susceptible of spontaneous decomposition; and from this diversity in the nature of their elements, the products of their analysis are not precisely the same.

Vegetable compounds are all formed by actions subservient to the general process of vegetation, and are derived from new combinations established by that process among the elements of the substances absorbed by the growing plant. Hence the relation of vegetation to chemistry, and the advantage of considering it so far as it is chemical, before proceeding to the history of the compounds themselves.

CHAP. I.

OF VEGETATION, AND THE FORMATION OF VEGETABLE COMPOUNDS.

Vegetables are, like animals, endowed with life. At one period, indeed, it was attempted to account for the functions they perform from their peculiar mechanism, and the action of mechanical powers. The rise of the sap, and the propulsion of their fluids, were ascribed to capillary attraction, and the motions of different parts to the elasticity of fibres. But such causes are utterly inadequate. The absorption of external matter, the movement of the fluids direct and retrograde, the secretions whence new products are formed, the motions of the leaves as they are excited by light and other external agents, the developement and growth of new parts, and the formation and evolution of the embryo plant,—are phenomena inexplicable on any principle of mechanism, and so strictly analogous to corresponding phenomena in the animal system, that they must be referred to a similar cause.

Vitality in vegetables observes even the same laws as that by which it is regulated in the animal frame. The motions and functions dependent on it require to be excited by the due application of external agents; if these are withdrawn, the functions languish or cease; if they act too forcibly, the vital power is impaired; if they have been previously abstracted, more vigorous action is exerted when their application is renewed; or if too suddenly and forcibly applied, the excitement may produce an exhaustion of power. The effects of soil, of moisture, of heat, light, and electricity, on plants,—their sleep, germination, efflorescence, fructification, and decay, afford many illustrations of the operation of this principle in conformity to these laws.

As vegetables and animals are thus endowed with similar powers, there is a similarity in their general structure and organization, and in the functions they perform. In vegetables these are indeed more simple than in the more perfect animals, but still the analogy is easily traced.

There moves through the vessels of plants a common juice or sap, supposed to be analogous to the blood of animals, and from changes in the composition of which the products of the plant are formed. The sap or common vessels, as they are named, rise longitudinally from the root to the upper extremities, passing beneath the cellular tissure of the stem and branches, or through the wood, and conveying apparently the fluid which is absorbed by the roots from the soil. Similar vessels run from the bark in an horizontal or oblique direction, conveying what may be absorbed from the atmosphere at the surface of the leaves, or of the branches or stem.

There are vessels distinct from these, named the Proper Vessels, in which the common sap has been supposed to suffer peculiar elaboration. They are situated principally in the cellular tissure and internal bark; they appear to descend towards the root, and to convey a fluid in that direction, as, when cut, the liquor which exudes comes from the upper margin of the incision.

As the common vessels can be traced from the root to the leaves, and the proper vessels descend in the opposite direction, it appears to follow, that any connection between them is established in the leaf. Darwin supposed that the large vessel, or bundle of vessels, which runs from the leaf-stalk through the centre of the leaf to its apex, is formed by the union of smaller sap-vessels; that the purpose it serves is to distribute the sap over the surface of the leaves in minute ramifications, in which it may be exposed to the action of air and light; and that the sap thus changed is brought back by other vessels which pass along the under surface of the leaf, unite at the commencement of the stalk, and probably form the proper vessels; in its progress through which, in different parts of the plant, the juice undergoes farther changes. And he stated some experiments on the absorption of coloured fluids, and their progress through the leaf, which accorded with this view. It has been more recently established by the experiments of Knight.

Another set of vessels have been observed in vegetables, the functions of which are not well ascertained,—those of a spiral form. They are found around the pith, in the slender branches, the leaf-stalk, and the petals of the flower. As they are always empty, they have been supposed to convey air; others have supposed them to be absorbents, which contract forcibly when cut, and hence discharge their contents. Knight regards them as subservient to the sap-vessels, as they are generally connected with them, and supposes, that by some mechanism they facilitate the propulsion of the sap.

The functions performed by vegetables, subservient to the formation of their chemical products, are, Absorption, Perspiration, Respiration, and Secretion.

Absorption is performed by vessels arising from the roots, and probably also from the bark and leaves. From the soil a large quantity of water appears to be taken up by these vessels, holding dissolved, it is probable, the soluble parts of the vegetable and animal matter which the soil contains, and a portion of its saline and earthy matter. This absorbed fluid appears to be the source of the sap; in its ascent it is changed in its qualities, acquiring greater specific gravity, and holding a larger portion of matter dissolved; changes which may arise in part from the action of the vessels through which it is propelled, and partly from the intermixture of the proper juices of the plant, and also, according to the conclusions drawn by Darwin and Knight, from the extraction of solid matter from the wood. According to the extent of these changes, and probably also according to the materials furnished from the soil, the sap varies in its qualities. Vauquelin found, that it always holds dissolved a considerable quantity of saline matter, principally acetate of potash and lime, and sometimes carbonate of lime, with smaller portions of sulphate, muriate, and nitrate of potash; it contains, too, vegetable matter, principally extract, and tannin, and sometimes sugar, the two latter being probably derived from intermixture of the proper juices. Knight always found the sap to be largely impregnated with air.

Perspiration is observed in plants, and when vegetation is vigorous, or under exposure to heat or light, takes place even to a very considerable extent. The perspired fluid appears to be chiefly water, with a slight impregnation of vegetable matter.

Respiration, or the function by which changes are produced in the composition of the surrounding air, is performed by vegetables by the medium of their leaves, is necessary to sustain their life, and is probably strictly connected with the chemical changes which constitute vegetation. Considerable difficulty, however, has been experienced in determining the precise nature of the reciprocal action exerted between a growing plant, and the surrounding atmosphere.

Priestley observed at an early period, that plants absorb carbonic acid from atmospheric air, when it is mixed with it, even in considerable quantity, and communicate to it oxygen; and this suggested the speculation already noticed, that vegetables and animals stand opposed to each other in the changes they produce in the atmosphere, and by this opposition preserve it at its due purity, and of uniform composition. This view, pleasing from its apparent adaptation to the œconomy of nature, was received without being submitted to very strict examination; though facts, not altogether in conformity to it, appeared to be established on other authorities. Even the experiments of Priestley afforded discordant results, and proved, that in some cases the changes produced in the air by vegetables are precisely the reverse of those whence his conclusions were drawn; and in those made by Scheele, the deterioration of the air and the production of carbonic acid gas were uniformly observed.

A fact ascertained by Ingenhouz appeared to point out the principle from which this discordance might be explained. He observed that the evolution of oxygen gas from the leaves of vegetables takes place principally when they are under exposure to solar light; whence he inferred, as the result of an extensive series of experiments, made by exposing the leaves of plants, their green shoots or branches, or even the entire vegetable, under water to the solar rays, that "oxygen is elaborated in the vessels or other organs of vegetables, by a vital action, excited and sustained by the light of the sun;" and he added a number of facts in proof of the conclusion that the organic structure of the vegetable is necessary to this; that it is the result of a function performed by it, and is therefore connected with the œconomy of the plant. The production of oxygen he found at the same time to be considerably dependant on the nature of the water under which the vegetable was immersed; and it has been more lately shewn, by the experiments of Sennebier, Woodhouse, and Saussure, that it is much connected with the presence of carbonic acid, so that in water entirely free from this, the evolution of oxygen is very inconsiderable, while in water impregnated with it, it is abundant. It may be inferred, therefore, that it is principally from the decomposition of the carbonic acid, by the powers of the plant, aided by the agency of the light, that the oxygen is evolved. Some have supposed even that the decomposition is produced by the action of the light alone, and that the vegetable matter affords merely a surface on which this acts on the water or the carbonic acid in a favourable manner—a supposition, however, which appears to be refuted by various facts stated by Ingenhouz, which prove the necessity of organic structure, and organic action, to the evolution of oxygen; particularly that other substances, which might equally afford a surface, as silk, have not the same effect; that the quantity evolved is greater, as the leaves are in a state of maturity and vigour; and that the evolution ceases when their life or organization is destroyed.

Still it is more satisfactory to determine the changes which the entire vegetable produces in the surrounding air, in its natural situation; and on this subject many experiments have been made. Priestley in general found, that air vitiated by respiration or combustion, has its purity restored by a growing plant, and that, by introducing the flexible shoots of plants into jars containing air, the air is ameliorated. Ingenhousz observed that plants confined in air, containing a portion of carbonic acid gas, decompose this gas, and produce oxygen when under direct exposure to solar light, but that if this is excluded, the reverse changes take place, oxygen is consumed, and carbonic acid formed. With this the experiments of Sennebier nearly correspond, the proportion of oxygen being increased in air, in which the branches of plants were placed over water and exposed to the sun, and this to a greater extent when the branches were removed during the night. Woodhouse at a later period drew the conclusion from his experiments, that plants confined in atmospheric air produce in general any change in it very slowly; carbonic acid was frequently formed, and oxygen consumed, but not, as he supposed, from any function of the vegetable, but rather from the chemical action of the oxygen on the carbonaceous matter of the plant; and the change more directly produced by the vital action of the vegetable, excited by solar light, is the decomposition of carbonic acid, and consequent evolution of oxygen; though, as the quantity of this acid diffused in the atmosphere is inconsiderable, vegetation, he supposes, can have little effect in preserving its purity.

The investigation of this subject has been prosecuted still more minutely by T. Saussure. The view suggested by his experiments, and which led to their more extensive prosecution, is, that carbonic acid is decomposed by growing vegetables, as the result of the process of vegetation; the carbon is fixed in the vegetable matter, contributing to the growth of the plant, and the formation of its products, part of the oxygen is also retained, and the remainder is evolved. Hence, when growing plants are placed in atmospheric air, to which carbonic acid has been added, and exposed to solar light, the carbonic acid, if not in too large quantity, disappears, oxygen is evolved, vegetation is vigorous, and the proportion of carbon in the plant is increased. It is this, according to Saussure, which is the source of the carbon in vegetables, for when they are made to vegetate in pure water, and in atmospheric air, deprived of carbonic acid, there is, he maintains, a mere enlargement of their bulk without any addition of weight. At the same time, the action of light is necessary to these changes. If it is excluded, the presence of carbonic acid gas, instead of being useful, is injurious, and no sensible quantity of it is decomposed; and a growing plant placed in common atmospheric air, under the exclusion of light, consumes oxygen, and forms carbonic acid. If the light be admitted, the reverse changes are established, and thus, under the alternate admission and exclusion of light, little sensible change is produced in the constitution of the air.

Mr Ellis has, in the last place, given another view of the changes produced by vegetables in atmospheric air, and of the connection of these with vegetation, nearly the reverse of that advanced by Saussure, though admitting a number of the same facts. His experiments prove, that growing plants uniformly, and in all periods of vegetation, consume the oxygen of the air, and form carbonic acid in quantity equivalent to the portion of oxygen thus consumed; this takes place even under clear day-light, and is only suspended, and the reverse changes established by the direct action of the solar rays. Carbonic acid is not necessary, he conceives, to their growth, for they die when it is abundantly supplied, if oxygen is not present; while they live and flourish as long as oxygen is supplied, though carbonic acid be completely abstracted.

It appears to be sufficiently established by the general results of the different experiments that have been made on this interesting subject, that growing vegetables produce very different changes on the air which surrounds them, according as they are exposed or not to the solar rays. Under this exposure they decompose carbonic acid when it is present, either in its elastic form or condensed by water, and exhale oxygen; when excluded from this, even though diffused light be present, they produce precisely the reverse changes, consume oxygen, and form carbonic acid.

The question, therefore, obviously is, which of these series of changes is the result of the natural function of the plant, connected with its growth and the formation of its products. And on this point Mr Ellis has very forcibly remarked, that as so many plants grow and form all their products without being directly exposed to the rays of the sun; and as at certain seasons, and in many climates, the degree of this exposure is inconsiderable compared with their seclusion from it, we are led to the conclusion that it cannot be essential to their growth, but that the changes which they more constantly produce, must be those on which vegetation depends.

This opinion may be just; yet the subject is not altogether free from obscurity; for, independent of the circumstance, that there is still some discordance with regard to some of the facts connected with it, it must be admitted as singular, that plants can without injury so change the state of the functions they perform, as at different times to produce changes precisely the reverse of each other, though extremely important in themselves; and farther, that they should exist in greatest vigour, and form their peculiar products in greatest perfection, generally in those climates, and universally in that season, in which they have, from situation with regard to solar light, been exerting to the greatest extent that very function with regard to the air, supposed to be least natural to them, or the reverse of that to which their economy is adapted, and which they usually perform. We have the farther difficulty, if we adopt this view, of accounting for the origin, (particularly in the case of plants growing when supplied only with water and atmospheric air), not only of the carbon which makes part of their substance, but of the much larger quantity which must be spent in this formation and evolution of carbonic acid. And, lastly, the experiments of Saussure appear to prove, that the decomposition of carbonic acid by plants, instead of being an unnecessary process, dependent on the accidental chemical agency of solar light, is essential to their growth; for he found, that if the small portion of carbonic acid which atmospheric air naturally contains were removed, by washing with lime-water, the vegetable to which such air was applied merely expanded, without any real addition of vegetable matter, while, when supplied with water and with atmospheric air in its natural state, the proportion of vegetable matter increased with its growth, proving that it had fixed the carbon of this carbonic acid.

It may be remarked, in concluding this subject, that the changes effected by plants in a state of full growth and vigour on the surrounding air, appear to be less than have been usually imagined; water is more essential to them, and they are unquestionably much less dependent than animals on the surrounding air. They require also a less supply of nutritious matter, as their growth is more slow, and they lose less by any excretion. There appears, too, to be a much greater diversity in plants than in animals with regard to their relation to the air, some affecting it very slowly, others producing changes in it more speedily, and some being injured by one gas in which others live sufficiently well.

Vegetables are capable of acting on the other aerial fluids besides atmospheric air or carbonic acid; but the facts on this subject are somewhat discordant, and are less interesting, as having little connection with vegetation.

Changes analogous to those produced by the leaves on the surrounding air, are produced by the action of other parts, particularly the stems and young green shoots. The leaves, however, are the proper respiratory organs of plants, and their importance is sufficiently shewn by the fact, that when they are destroyed during the period of rapid vegetation, the plant decays, and even dies. The under surface of the leaf appears to perform the functions of transpiration and absorption of watery vapour, while it is at the upper surface that the chemical changes produced by the action of light principally take place.

Secretion, or a process analogous to it, is performed by vegetables; in other words, from the common juice or sap very different products are formed, by the action of the vessels giving rise to new combinations of the principles it affords. These changes have been supposed, but without any sufficient proof, to be produced principally in the utricles or bundles of vessels situated in the stem and other parts. The secreted products form the vegetable proximate principles, and they are adapted to different purposes in the economy of the plant.

Having traced the functions of vegetables, it remains to connect with them the general process of vegetation, and the consequent formation of the vegetable compounds.

The seed of a vegetable consists of two principal parts, —the germ, or part endowed with life, and the cotyledons or seed-lobes connected with it, and which, in the commencement of its growth, afford it nutrition and support. In the germ two parts are discoverable,—the radicle, which descends from the seed forming the root, and the plumula forming the stem; and it is connected with the cotyledons by slender vessels, which ramify through their substance, and unite at their connection with the germ. When the seed is planted in the ground, or placed in other situations favourable to its vegetation, it absorbs moisture, and swells; the radicle shoots out, and the substance of the seed-lobes soon suffers a change in its qualities, the fecula of which it principally consists being converted into sugar. This constitutes the vegetable function of germination, the first stage in the process of vegetation.

The presence of oxygen is indispensable to germination.

If seeds moistened are placed *in vacuo*, or if they are confined in nitrogen or hydrogen gas, or carbonic acid, they do not germinate; when immersed in water from which the atmospheric air is excluded, they swell, and the radicle is formed, but vegetation makes no farther progress; the life of the germ is soon lost, and the chemical decomposition of the matter of the seed takes place. But if atmospheric air or oxygen be admitted, germination soon commences, and if the seed be placed in a favourable situation, proceeds to vegetation. Humidity is essential to the process, probably by favouring the developement and action of the minute vessels of the embryo plant, as well as the chemical changes, which convert the substance of the seed into matter adapted to its nutrition. A certain temperature, always superior to the freezing-point of water, is also necessary, and probably operates both by favouring these changes, and exciting the vital powers of the germ. Light rather retards the process, and, indeed, under full exposure to light, seeds do not germinate, or if they do, the plant on its evolution is extremely weak. When placed in the soil, therefore, seeds are under the most favourable situation for germination. The direct action of light is excluded, from the looseness of the soil the air is admitted, the due degree of humidity is supplied, and the temperature is preserved uniform.

During germination, the oxygen of the air is consumed, and carbonic acid is formed; the volume of the air is not sensibly altered; and as in the change of oxygen by combination with carbon into carbonic acid, there is no change of volume, this proves, that no part of the oxygen consumed in germination is absorbed by the seed, but that it merely combines with a portion of its carbon. Some chemists have supposed, however, that a portion of water is decomposed during the process, the oxygen and hydrogen of which combines with the elements of the fecula of the seed-lobes.

By the chemical changes which occur in germination, the fecula of the seed is converted into sugar. This appears designed to serve as nourishment to the young plant; being soluble in water, it is absorbed in a state of solution by the vessels of the radicle, which begin to expand; and a supply of nutritious matter is thus afforded independent of any external source, until the powers of the plant are developed. The necessity of this is shewn by the fact, that if the seed-lobes are removed from the germ, the latter, when planted in the earth, either does not vegetate, or does so very imperfectly, and soon dies.

When germination has been established, the powers of the plant are excited, and its parts expand. The radicle first shoots out, penetrates the soil, and increases in length; the plumula rises from the ground to form the stem, and the different organs are successively unfolded, according to the structure of the plant. Nutritious matter is now supplied to it from without, and from changes in the substances it receives, all its products are formed.

Air and water are the principal vehicles of the food of plants. The soil, except with regard to some vegetables, affords little directly nutritious, and scarcely any of the earthy matter, it has been sufficiently demonstrated, is absorbed. The earth in which a plant is made to grow, it has been shewn by experiment, suffers little diminution of weight, though the plant placed in it has increased greatly in bulk. Many vegetables grow when supplied with pure water alone. Parasitic plants, and those which grow on stones or rocks, can derive no nourishment from the earth; and the analysis of vegetable matter has shown, that their solid substance, and all their products, are formed of principles very different from those of which the soil is composed.

Water enters largely into the composition of vegetable matter; but it has also been concluded that it suffers decomposition in the process of vegetation, and that its hydrogen, with at least a part of its oxygen, contribute to the formation of the vegetable products. The conclusion has been drawn partly from the consideration, that in plants supported on air and water alone, there is no other source whence the hydrogen so abundant in their composition can be derived, and partly from the fact that vegetables growing in water exhale oxygen, at least when exposed to the action of solar light, the source of which, it is inferred, can only be the water which the light enables the plant to decompose.

From the atmospheric air, plants, it has been supposed, may receive carbonic acid, and this decomposed may be the source of the carbon, which, with hydrogen and oxygen, is the basis of their composition. In support of this, experiments have been stated by T. Saussure and others, proving that in an atmosphere composed partly of carbonic acid, growing plants cause a quantity of it to disappear, and that when supplied even with the small portion of carbonic acid contained in common atmospheric air, they grow, and increase their quantity of carbon, which they do not do if the carbonic acid of the air has been previously abstracted. This, however, must be regarded as doubtful, if the fact be established, that the immediate result of vegetation is to consume the oxygen of the air, and to convert it into carbonic acid. The influence of the nitrogen of the atmosphere in vegetation appears to be negative; that of the oxygen must remain doubtful, until it is clearly established whether the consumption of oxygen and formation of carbonic acid, or the decomposition of carbonic acid and evolution of oxygen, are the changes connected with the growth of plants.

It must be admitted, on the general view of the subject, that in the present state of our knowledge, there are considerable difficulties in accounting for the nutrition and growth of those plants which are supplied with air and water alone,—an admission, however, which will be more easily received, since the recent discoveries in chemistry abundantly demonstrate that we know little of the ultimate principles of bodies, and confirm the suspicion, that those which in our speculations have been regarded as simple, are probably very remote from an elementary state.

It is farther to be stated, however, that it has been questioned whether plants do grow and flourish, when supplied with air and water alone. There is, it has been contended, a mere developement of parts without any actual increase of vegetable matter, unless where other sources have existed whence nutrition could be conveyed. Thus, Hassenfratz has affirmed, that in plants which expand when merely supplied with water, as hyacinths, kidney-beans, or cresses, the vegetation is in this situation always imperfect, and the plants, when dried, afford no more carbon than what is contained in the seed or bulb. Saussure remarks, that these and similar plants, if supplied merely with distilled water, though they advance so far in growth, do not come to maturity. And Knight has remarked, that bulbous and tuberose roots contain within them the matter which serves for the developement of their parts, and their growth, to a certain extent. In the celebrated experiment of Van Helmont, in which a small willow was placed in a vessel containing dried earth, and supplied with water for several years, until it had grown to such a size as to have increased in weight from 5 to 169 pounds, though the earth had lost only two ounces of weight, and in other experiments of a similar kind, it has been contended, that sources of fallacy exist, particularly in the foreign matter conveyed by the water with which the plant was supplied.

It may be true, that in many plants vegetation, in the first stages of their growth, may be little more than an expansion of their substance by the operation of humidity, and the vital powers of the plant; and it is also not to be doubted, that there are many, the growth of which is imperfect unless they receive nutritious matter from the soil. But still these facts are insufficient to invalidate the conclusion, that vegetation may be supported by air and water alone, and that many plants supplied with these will flourish, and form their peculiar products.

This conclusion is in fact established, if we attend merely to the circumstances connected with the growth of a large vegetable, as of any of our common trees. Its roots stretch to no great extent or depth in the soil, and that soil does not require to be renewed, or to receive any supply of manure. Nay, frequently the situation is such, that nothing is afforded but a support by which the plant is exposed to the air, and occasionally supplied with water. Yet the growth of the tree advances, its solid matter increases, and in many of them much vegetable matter is annually lost in the fruit and foliage. It is obvious, that the portion of soil with which the plant can be supposed to communicate could not have contained the matter from which this is derived, and there is no external supply but from water and atmospheric air.

There are, however, many vegetables which require other nutritious substances for their support and growth. This is proved by the most familiar facts in agriculture. Many vegetables flourish only in certain soils; those which require a rich soil vegetate only feebly when made to grow in a poorer, and many exhaust that in which they grow, so that it requires to be renewed by manure.

The two series of facts on this subject apparently opposed to each other,—one proving that vegetables grow when supplied with air and water alone, the other equally proving that vegetation under such circumstances is imperfect, and that a supply of matter more directly nutritious is required,—perhaps admit of being reconciled. In plants which expand rapidly, and soon proceed to maturity, the aid of nutritious matter may be required to bring them to perfection; the developement of their parts may so far exceed the slow supply of principles which they can assimilate from water and atmospheric air, that they decay before their vegetation under such circumstances can be completed. But in plants which grow more slowly, air and water may afford a sufficient supply. It is accordingly those vegetables which grow with most rapidity, and which afford the largest produce of seed or fruit compared with the plant at the commencement of its growth, that require a rich soil. Such are those plants which are cultivated for the nourishment of animals.

Of the substances which contribute to the growth of vegetables besides air and water, the most important is vegetable or animal matter in a state of decomposition. This constitutes the richness or fertility of a soil; and its operation probably arises partly from its affording matter already assimilated to the nature of the vegetable, which is directly absorbed, dissolved or suspended in water, and partly from the elastic products evolved during its slow decomposition, which contain the principles required for vegetable nutrition in comparatively a condensed state, and which may also enter the vegetable by absorption, either in the elastic form, or imbibed by the water of the soil.

Besides this species of manure, which is perhaps alone directly nutritious, there are others scarcely less useful, which appear to operate either by accelerating the decomposition of vegetable and animal matter, or by exciting the plant to more vigorous action. Such is lime, the utility of which is sufficiently established, both in increasing the products of vegetation, and improving their quality. The theory of its operation cannot be said to be fully understood; it may in part act by its intermixture with the other earths composing the soil, giving those qualities most favourable to vegetation which depend on its cohesion; it may also stimulate the absorbent vessels of the root; it may, either in its entire state, or in that of its elements, enter into the composition of the vegetable products; but its principal operation probably is that of accelerating, by its chemical action, the decomposition of matter which would otherwise remain inert: hence its utility is greatest in soils abounding with vegetable and animal matter; and when this is exhausted, less advantage is derived from it, until this species of manure is supplied. It acts most powerfully in its pure state, though similar advantages are derived from it to a certain extent, when it is combined with carbonic or sulphuric acid.

The nature of the soil, with regard to its earthy and metallic ingredients, has likewise an important influence on vegetation. These may have a diversity of effect in exciting the actions of the vessels of the roots; if absorbed even in sparing quantity, they may have a similar effect on other organs of the plant; and it is obvious that they must differ in the mechanical support they afford, in the facility with which they allow the roots to extend, and in the force with which they absorb water, and retain it. As these qualities must be various in their relation to different plants, some requiring a more firm support, or a more ample supply of humidity than others, it is not possible to determine exactly what constitutes a well-constructed soil. Experiments made by Tillet on the comparative powers of various earthy mixtures in sustaining the vegetation of those plants which are cultivated for nourishment, such as wheat, have shewn that there is a considerable latitude in this respect,—the plants flourishing in mixtures of very different kinds. Giobert has also given the analysis of soils actually barren and fertile, whence it appears that a large proportion of siliceous earth is useful. But all such observations are necessarily limited, as the qualities of the soil are to be compared, not only with regard to the particular vegetables it supports, but according to the nature of the subsoil, the declivity, and the humidity and temperature of the climate. When there is an excess of argil or clay, water is imbibed slowly, but is strongly retained; and in drying, the mass hardens and contracts. A larger proportion of silex, in a state of division more or less fine, gives a greater degree of porosity; lime corrects an excess of either quality; and much of the excellence of the soil probably depends, not only on the proportions, but on the intimate and uniform mixture of the ingredients, and the degree of comminution to which they are reduced. A fertile soil, analysed by Mr Davy, was found to be composed in 100 parts of 11 of carbonate of lime, 25 of siliceous sand, 45 of finely divided clay, 9 of animal and vegetable matter, 4 of water, and a little phosphate of lime.

Lastly, in the process of vegetation, the influence of heat and light is conspicuous. Both operate probably by exciting the actions of vegetables connected with their vitality; and from the change to which solar light gives rise in the reciprocal action between the growing plant and the atmosphere, it is obvious, that it also in part acts as a chemical power. Its influence is well marked in the changes which plants suffer when they are secluded from light; they become of a pale colour, which soon changes to green when the light is admitted. This action is principally exerted on the sap circulating through the leaves, and it is accordingly at the margin of the leaf that the change of colour first appears.

Such are the circumstances most materially influencing vegetation; and considering the operation of all of them, the following may be presented as the theory of the process which the present state of our knowledge suggests. Regarding germination as its first stage, the seed exposed to atmospheric air expands; and the farinaceous matter, by the action of the oxygen of the air, is converted into sugar, which serves as food to the infant plant. Its organs are gradually unfolded, and its nourishment received from a different source; water, pure, or holding vegetable and animal matter in solution, is absorbed by the roots; and, in a soil containing decomposing vegetable and animal matter, different aërial fluids are received, and mingled with the sap. This, in its progress through the root, dissolves even part of the vegetable matter; and from this, the plant, in the first stages of its growth, is better enabled to form its products. It is brought to the leaves of the vegetable, and presented under an extensive surface, covered with a very thin membrane, to the action of the air and light; part of its water transpires; carbonic acid, and other elastic fluids from the atmosphere, are perhaps absorbed; and, by the action of the vessels, assisted by the chemical agency of light, new combinations are established, and the proper juice of the plant is formed. This is conveyed by the footstalk of the leaf, and by vessels proceeding downwards through the bark, or between it and the wood: it is deposited in different parts, or is still farther changed in its progress,—changes from which the peculiar vegetable products are formed.

From the substances conveyed to the plant from the air, water, and soil, must no doubt be derived all the elements of which its products are formed. But in the uncertain state of our knowledge with regard to what principles are truly elementary, it is perhaps in vain to attempt to trace with certainty the source of those ultimate principles which the vegetable analysis affords. There are found in the products of the vegetable kingdom, though in very different proportions, oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, the fixed alkalis, lime, magnesia, argil, and silex, and several metals, particularly iron, manganese, and, as it has likewise been affirmed, gold. With regard to oxygen and hydrogen there is no difficulty, as these are abundantly supplied from water. From a common soil, containing always vegetable and animal matter, carbon may be derived, but in plants growing merely in water and air, there is the difficulty, as has been already stated, if we do not admit of the absorption of carbonic acid from the atmosphere, of accounting for the oxygen origin of the carbon necessary to their growth, and still more for the larger quantity disengaged in the state of carbonic acid, when the plant is not under the action of light. Nitrogen, if it is not a compound body, may be derived from the atmosphere. With regard to the other substances present in more sparing quantity, little can be said with precision; they may in general be derived from the soil; and the researches of Saussure have established some important facts in proof that the saline, earthy, and metallic ingredients have this origin; at the same time it is sufficiently possible that all these principles may be compounds of elements more subtle, at present unknown to us, and may be formed in the processes of vegetation; or the opposite supposition is equally probable, that, whether simple or compound, they may be evolved from the decomposition of others, which our imperfect knowledge has ranked as elementary.

CHAP. II.

OF THE PROXIMATE PRINCIPLES OF VEGETABLES.

THE products of vegetation are extremely diversified; but in submitting them to chemical arrangement, they are reduced to a few species, named the Proximate Principles of Vegetables. These are distinguished entirely by chemical characters; the substances arranged under each species, may differ somewhat in their sensible qualities, but if they have that agreement in chemical properties which fixes the species, these less important differences are disregarded, as indeed they do not fall under the investigation of the chemist.

These proximate principles exist in the different parts of plants, and in their products, either insulated, or in states of mixture or combination; and, in the latter case, are separated by processes founded on their chemical relations, as by the action of different solvents, or by the application of heat. If the leaves of a plant, for example, are macerated with water, its entire substance is not dissolved, but it may yield a matter soluble in water; if distilled, a volatile principle may be obtained; if macerated in alkohol, a portion of matter may be extracted, which the water had not dissolved; and by multiplied operations of this kind, a number of distinct substances are obtained.

The diversities of properties in these principles, and from which the discrimination between them is established, arise from differences in their chemical constitution. Still they have all the general characters of vegetable matter, and in their analysis afford similar products, diversified principally in the proportions.

This analysis is effected in various modes. The most general is the analysis by heat, and this has been much prosecuted by chemists. When a vegetable substance is exposed to a temperature superior to 212°, after the superfluous water is dissipated, its decomposition commences, from the re-action of its elements, and the new combinations into which they pass. A dark-coloured empyreumatic oil distils over with a portion of an acid liquor; carbonic acid, carbonic oxide, and carburetted hydrogen gases are disengaged, and a quantity of charcoal remains, frequently containing portions of saline, earthy, or metallic matter. These products are not those which existed in the vegetable matter, but are compounds, arising from the decomposition of the proximate principle, and the union of the elements in new modes and proportions. The oil is produced by the union of part of the hydrogen with part of the carbon of the vegetable matter; the acid, from the combination of another portion of carbon and hydrogen with oxygen; the carbonic acid, oxide, and carburetted hydrogen, are similar products; and the remaining charcoal arises from the excess of carbon not spent in the formation of these compounds.

From such an analysis, however, little is learned of the nature of the matter subjected to it; for although the products can be collected, and their composition may be ascertained, yet experiments of this kind are liable to sources of error nearly inappreciable. From slight variations in the state of the matter analysed, with respect to humidity, or from still slighter variation of temperature in conducting the experiment, important differences in the results will be produced; and we are likewise unable to ascertain what quantities of the products of the analysis have pre-existed in the vegetable matter, or have been actually formed. We acquire, therefore, only some general information. If much acid has been afforded by the analysis, we conclude that the matter analysed has contained a large proportion of oxygen, as this principle enters so largely into the composition of acids. If much oil has been obtained, we conclude, by a similar mode of reasoning, that hydrogen has been an abundant element of the matter analysed. From the production of ammonia or prussic acid, we infer the existence of nitrogen: from the quantity of charcoal, we draw some conclusion as to th quantity of carbon existing in the vegetable; and by burning this charcoal, we discover the quantities and kinds o earthy and metallic mater which it has contained.

Sometimes vegetable substances are analysed, by heating them in contact with atmospheric air, so as to excite combustion; and from the products, determining the nature and proportions of the constituent principles. Certain principles can likewise be analysed by subjecting them to spontaneous decomposition, as saccharine matter, for example, by the process of fermentation: and, lastly, vegetable analysis may in some cases be effected by the agency of the nitric acid, which produces oxygenation of the vegetable matter, and by the product indicates the principles of which it has been formed.

The proximate principles of vegetables, or those compounds of their ultimate principles which, by mixture or combination, form every kind of vegetable matter, have been reduced to the following species: Mucilage or Gum, Fecula, Sugar, Gluten, Albumen, Jelly, Fixed Oil, Volatile Oil, Camphor, Wax, Resin, Extract, Cautchouc, Tannin, Acids, and the Ligneous Fibre. To these have been added some principles more subtle, or more doubtful; as the Aroma-Narcotic Principle, and Colouring Matter.

SECT. I.—*Mucilage, or Gum.*

THIS is one of the most abundant proximate principles of vegetable matter, and it seems to be the first product of the changes which the sap suffers from the action of the vessels. It is found in all young plants, in their roots, stalks, and leaves, and particularly in their seeds; and it is often present in such large quantity in their vessels as to be discharged by spontaneous exudation. It is also frequently combined with other proximate principles, from which it may be separated; but its characters are best taken from those varieties of it in which it exists in a pure form.

Pure gum is usually in small fragments, brittle, and semi-pellucid, of a white, yellowish, or reddish colour. It is inodorous and insipid, neither fusible nor volatile, and not inflammable in the strict sense of the term, for although it is charred when heated under exposure to the air, it scarcely burns.

Gum is soluble in water, either cold or warm, in every proportion, forming a thick viscid solution, which is named Mucilage, and from which the gum may be obtained by evaporation in its original state.

A chemical character serving to distinguish gum, is its perfect insolubility in alkohol; it is even precipitated by this re-agent from its watery solution. It is likewise insoluble in ether, or in oils; but triturated with oils, it diffuses them in water.

Gum suffers decomposition from the more powerful acids. Sulphuric acid chars it, causing at the same time a formation of water and acetic acid. Nitric acid causes the formation of oxalic, malic, and saccho-lactic acids, in proportions varying according to the concentration of the acid. Oxy-muriatic acid converts it almost entirely into citric acid. Muriatic acid dissolves it without forming from it any new product.

The alkalis and alkaline earths, in solution in water, dissolve gum without producing on it much change. Some of the earthy and metallic salts give rise to changes which serve to distinguish it; in particular, the acetate of lead throws down a copious white precipitate from its solution, while the super-acetate has no sensible effect on it, and a solution of silicated potash renders it quite opaque.

Gum is decomposed by heat, affording a large quantity of pyro-mucous, or empyreumatic acetic acid, with empyreumatic oil, carbonic acid, and carburetted hydrogen gases, ammonia, and a residuum of charcoal, which affords a little phosphate of lime. The principal elements of these products are carbon, hydrogen, and oxygen; and from the large quantity of acid produced, the proportion of oxygen may be inferred to be large. The production of ammonia indicates the presence of nitrogen, and the lime of the residual charcoal is capable of being discovered by tests in gum, being precipitated in particular from its solution by oxalic acid. It is from the presence of lime that gum appears to be incapable of passing into the vinous fermentation, this earth counteracting that process; and it is this chiefly which distinguishes gum from fecula, another proximate principle of vegetables, to which it has a great resemblance.

The purest gums are obtained by spontaneous exudation, such are the gum-arabic and the cherry-tree, and plum-tree gum. Gum-tragacanth differs a little from pure gum, particularly in being imperfectly dissolved by cold water, though with boiling water it forms a very viscid solution. The mucilages extracted by the maceration of water on seeds and roots which abound in gummy matter, present also some appearances with re-agents different from pure gum,—differences, however, of little importance.

Gum, in the state of mucilage, can be extracted in considerable quantity from a number of indigenous plants, by maceration in water, and a supply of it has thus been procured for several purposes in the arts, particularly in calico-printing. By a slight preparation, too, it may be obtained from the greater number of the lichens, these being freed from the outer skin, and boiled strongly with water, to which a small quantity of carbonate of potash has been added, and the mucilaginous liquid being reduced by evaporation to the requisite consistence.

Gum is used in pharmacy to suspend oils, balsams, and resins in water; and in several arts is employed, from its adhesive quality.

SECT. II.—*Of Fecula, or Starch.*

THE principle distinguished by this name, forms the principal part of the nutritive grains and roots, and is extracted from them by the action of water, the grain or root, after being cleansed, being bruised, and beat with the water; the fecula is extracted in the state of a powder, which is diffused through the water, and speedily subsides. Starch is the fecula of wheat, and is extracted by a process of this kind; and other varieties of it are obtained from rye, from the potatoe, and from the roots, stems, and seeds of a number of plants. It is sometimes extracted, even quite mild, from poisonous or acrid plants, the acrid matter being dissolved by the water, and thus entirely abstracted.

Fecula is usually in the form of a light white powder, very soft and smooth to the touch, and apparently composed of impalpable brilliant grains; it is insipid and inodorous, though it sometimes has colour and taste, from other principles which adhere to it.

The property characteristic of this principle is insolubility in cold water, while it is perfectly soluble in hot water, forming a solution viscid or gelatinous. The solution of it takes place when the temperature is raised to 160° or 180°; and if the water is dissipated by evaporation, the solid matter is soluble as before. It is insoluble in alkohol and ether, and alkohol precipitates it from its watery solution, like gum.

Fecula is capable of passing into the vinous fermentation, and of undergoing the previous change of conversion into saccharine matter. This happens in the process of the germination of seeds, and it is from this property that the different nutritive grains form fermented liquors.

It is decomposed by heat, blackens, and forms at length a spongy charcoal, and if heated strongly, burns. The products of its decomposition in close vessels are an acid liquor, which is diluted empyreumatic acetic acid, a little empyreumatic oil, carbonic acid, and carburetted hydrogen, and a residuum of charcoal. From these products it may be inferred to be a compound of carbon, hydrogen, and oxygen.

The acids decompose fecula with results somewhat similar to those which they produce on gum. Sulphuric acid chars it, and forms water and acetic acid. Nitric acid converts it into malic and oxalic acids.

The alkalis appear to dissolve it, as their solutions reduce it to the consistence of a jelly, even without the aid of heat. It is precipitated from its solution in water by acetate of lead, and nitro-muriate of tin, but not by silicated potash,—a property in which it differs from gum.

Fecula, in a number of its properties, bears a resemblance to gum, and still more to the mucilages extracted by maceration from the seeds and roots of plants, and it is probably formed from mucilage in the process of vegetation. It forms the principal part of the nutritive seeds and roots, and is itself highly nutritious; hence it is used in its pure state as an article of diet, salop, sago, arrow-root powder, and cassava, being varieties of it. Wheat affords it in larger quantity than any other vegetable, and in a state of perfect purity. The potatoe also affords a large quantity of it, and the starch of both these vegetables is used for the adhesive property of its gelatinous solution.

A substance obtained in the form of a powder from the root of elecampane, (Inula helenium), and distinguished as a peculiar principle, appears to be merely a variety of fecula, distinguished by inferior solubility in water, so that, although dissolved by boiling water, the greater part of it separates as the water cools.

Sect. III.—*Of Jelly.*

The juices of certain fruits, as the currant, if not too watery, concrete into a kind of tremulous jelly. The substance communicating this property is very sparingly soluble in cold water, while it dissolves easily in boiling water, the solution as it cools becoming gelatinous. In this leading character, therefore, it resembles fecula. As an acid usually accompanies it, it is not improbable it may owe to this the slight modification of its properties.

When procured by evaporation in a solid state, Vauquelin found it to be transparent. It is dissolved by the alkalis, and in the dilute acids. Nitric acid converts it into oxalic acid, without disengaging from it any sensible proportion of nitrogen. It is precipitated by infusion of galls. Decomposed by heat, it affords, along with the elastic fluids usually disengaged in the decomposition of vegetable matter, much empyreumatic acetic acid, little oil, and scarcely any ammonia.

It is from the presence of this principle, that the juice of the currant and other fruits form a jelly when prepared with sugar. To form the gelatinous consistence, it is necessary that there should be a certain proportion between it and the water; by long boiling, too, the property is lost. Hence the reason, as Vauquelin has remarked, that in preparing the preserved jellies of these fruits, if the juice is too watery, or the proportion of sugar not sufficiently large, so that it is necessary to continue the boiling long, the gelatinous consistence is not acquired.

SECT. IV.—*Of Sugar.*

SUGAR is an abundant vegetable product, mixed frequently with other principles, but frequently also secreted in a more pure form. It thus exists as the chief constituent part of the sweet juices of many fruits; and there are plants, as the sugar-cane and the sugar-maple, which afford it in large quantity. From both of these it is extracted, and even from other plants, for the numerous uses to which it is applied.

The juice of the sugar-cane, at a certain state of maturity, is highly saccharine. It is expressed and boiled, a quantity of lime being added, the operation of which appears to be that of neutralizing a portion of oxalic acid in the juice, which prevents the concretion of the sugar. The juice, after the proper decoction is allowed to remain at rest until it become clear, is boiled down in another vessel, until, on cooling, the sugar separates in a concrete state, a sweet liquor remaining, Molasses, which is drained off. The saccharine matter thus obtained, being not altogether pure, is purified by boiling its solution in lime water, with the addition of a quantity of blood; the lime neutralizing any acid that may be still present, the blood coagulating, and the coagulum entangling the impurities. The liquor, after being sufficiently concentrated, is drawn off, and run into inverted conical moulds of clay, in which it becomes concrete; the base of the inverted cone is then covered with clay which is moistened with water, and this filtrating slowly through the mass, removes any saccharine liquor; the mass is afterwards strongly dried. By a similar process, sugar is obtained from the juice of the sugar-maple; and from the juice expressed from the roots of the Beet, Parsnip, and some similar plants.

Sugar, when pure, has a sweet taste, free from any peculiar flavour; it is of a white colour, and appears in the mass to consist of brilliant grains; it also assumes, in becoming concrete from its watery solution, a regular crystalline form, that of a rhomboidal prism; the crystals are transparent.

Sugar is soluble in water; at the temperature of 50 of Fahrenheit it does not require much more than an equal weight. Boiling water dissolves nearly any quantity of it. Its solution is more or less viscid.

Sugar is also soluble in alkohol; and this solution, when concentrated by evaporation, likewise affords crystals.

When exposed to heat, sugar is blackened, swells up, and burns to a coal; if the heat is strong, its combustion is attended with flame. The products are carbonic acid and water. Exposed to heat in close vessels, it yields a considerable quantity, rather more than half its weight, of weak empyreumatic acetic acid, a small quantity of empyreumatic oil, with carbonic acid, and carburetted hydrogen gases, the residuum being charcoal. These products into which the sugar is resolved, consist of carbon, hydrogen, and oxygen; and these may be stated as its ultimate constituents. From the large quantity of acid which its analysis affords, it appears to contain more oxygen than any other vegetable substance that is not acid.

By the abstraction of oxygen, sugar is converted into a substance somewhat similar to gum, a change produced in it, in some experiments by Cruickshank, by the action of phosphuret of lime.

Sugar is decomposed by the acids. Sulphuric acid causes an evolution of charcoal. Nitric acid is rapidly decomposed by yielding oxygen, and an acid is formed, the same with one which exists native in vegetables, the oxalic acid, a smaller portion of another, the malic being also frequently produced. Liquid oxy-muriatic acid converts it into citric acid.

The alkalis form combinations with sugar, in which the sweet taste is lost, though it is restored when the alkali is neutralized by an acid. The compound, it is singular, is not soluble in alkohol, though both its ingredients are. The action of the alkaline earths is similar, and both lime and strontites are rendered more soluble in water by the combination. The compounds have a bitter astringent taste, and their solutions are viscid and tenacious.

Sugar being highly nutritious, is, independent of its sweet taste, of some importance as an article of diet. Its solution, syrup as it is named, is employed in pharmacy; and sugar itself enters into the composition of ink, and of some pigments and varnishes, to give to them a degree of lustre.

Honey is another vegetable product, similar in many of its properties to sugar; nor has any essential difference been pointed out between them, except the natural fluidity of honey, and perhaps its viscosity. A species of sugar can be obtained from honey by the action of alkohol, or by clarifying it by a moderate heat, and the action of carbonate of lime. This sugar does not crystallize so readily as common sugar, and it suffers changes somewhat peculiar from the alkalis and earths, effervescence being produced, and a brown or black colour acquired. Some have supposed it to be a compound of sugar and mucilage.

Honey is formed in the flowers of plants, and is always exposed, frequently by a very complicated organization, to the atmospheric air. It has been supposed to be designed in the vegetable to receive and retain the fecundating pollen from the male parts, as its secretion diminishes or ceases when the fecundation is completed. A number of insects feed upon it, and it is collected in large quantity by the bee.

The saccharine matter formed in certain morbid states of the animal economy, giving rise to the disease named Diabetes, is very similar in its properties to the sugar o honey.

Manna is a concrete juice, which, from its sweet taste, may be judged to be highly saccharine. It has similar properties, and appears to owe any peculiar qualities belonging to it, to a portion of extractive or mucilaginous matter with which the sugar that is its basis is mixed.

Sect. V.—*Of Gluten, Albumen, &c.*

In the analysis of the flour of wheat by the affusion of water on the paste kneaded in the hand, the saccharine and mucilaginous matter is dissolved, and the fecula is carried off diffused in the water; there remains a viscuous, elastic substance, which, from its resemblance in some properties to an animal product named Gluten, has obtained the name of Vegetable Gluten. It amounts, apart from the water combined with it in its extraction, to a twelfth part of the weight of the flour, and is equal, in the humid state in which it is obtained, to from a third to a fifth of the weight. In the other nutritive grains, it is contained in much smaller quantity, and in some of them, as well as in the nutritive roots, there are no traces of it. It appears, however, to be contained in the expressed juices of some plants.

Gluten, combined with water in the state in which it is obtained from the flour of wheat, is soft and ductile, distinctly fibrous in its texture, and highly tenacious and elastic, so that it can be stretched out to great length; but when the stretching force is withdrawn, speedily shrinks into its former dimensions. It is of a greyish colour, and has scarcely any odour or taste.

By a moderate heat, the water contained in gluten in this state is dissipated; it becomes hard and brittle, and is then not liable to much change. But soft gluten soon passes into a state of putrefaction similar to that which animal matter suffers, and there is a formation of ammonia, acetic acid, and an oily matter. Under water it does not putrefy so readily, the formation of acetic acid apparently preventing this, and dissolving a small portion of gluten; the decomposition, however, gradually proceeds, and is at length marked by the offensive odour which distinguishes putrefaction.

Gluten is not soluble in water, unless it has undergone a certain degree of change by spontaneous decomposition, and even then the portion dissolved is very inconsiderable. It is likewise insoluble in alkohol, unless when it is in a similar decomposed state.

The action of the acids on gluten affords different results, according to their state of concentration, and the facility with which they yield oxygen. The weaker acids, particularly the acetic, dissolve it without producing in it much change. Muriatic acid acts in a similar manner; oxy-muriatic acid changes it into a yellowish flocculent substance. Sulphuric acid chars it, and causes an evolution of carburetted hydrogen, and formation of ammonia and acetic acid. Nitric acid disengages from it nitrogen gas, and forms oxalic and malic acids.

Gluten is dissolved by the alkaline solutions, aided by heat, suffering at the same time a change in its properties from partial decomposition.

This principle is decomposed by heat, and the products yielded by this decomposition are very similar to those from animal substances. A large quantity of carbonate of ammonia is formed, with empyreumatic oil, and a little prussic acid; carburetted hydrogen gas is disengaged, and there is a residuum of charcoal. The production of ammonia indicates the predominance of nitrogen in its composition; and this is shewn by the disengagement of this gas when gluten is acted on by nitric acid: the large quantity of oil farther indicates the presence of hydrogen in considerable proportion, while, from no acid being produced, it may be inferred to contain little oxygen. Phosphorus appears to exist in it in small quantity.

Gluten thus appears to be strictly analogous in composition to animal matter. Hence it adds to the nutritive quality of the grains in which it exists, and to this, in part at least, is to be ascribed the superiority of wheat. It communicates also that superiority which the bread prepared from wheat has to that from the other grains; as the flower of wheat made into a paste with water, forms from the presence of gluten a ductile mass, which, when rendered porous by the disengagement of carbonic acid, from the slight fermentation excited by the action of the leaven, remains after being baked, light and spongy, while the flower of other grains does not undergo this change, but forms rather friable pastes.

From the juices of certain plants, those generally of the cruciform kind, a flocculent substance separates by coagulation when they are exposed to heat; and it is also separated by the action of acids. This property of being coagulated by heat, and by acids, being characteristic of the animal principle named albumen, the matter thus separated has been considered as approaching to this, and has received the name of Vegetable Albumen. Rouelle long ago regarded it as analogous to gluten; and from the more recent observations of Proust, it appears to be merely a variety of it, deprived of the elasticity, and some of the other physical properties of gluten in its common state, from the nature of the process by which it is obtained. It not only exists in the cruciform plants, but likewise in the grape, apple, and other fruits, in the acorn, horse-chesnut, and other beans; and it is supposed to form the base of the green fecula which subsides from the expressed juices of a number of herbs.

Though this principle is probably a variety of gluten, the singular fact has been established, that there does exist in the vegetable kingdom a principle which has almost all the properties of animal albumen, and which, of all the varieties of vegetable matter, approaches most nearly in its character to animal substances. It exists in the juice of a plant, the carica papya, a native of the Isle of France. This juice, when it issues from the tree, is white as milk;

in a few minutes it coagulates, and a flocculent substance separates, which floats in the liquid now become transparent. If the juice be inspissated, it affords a solid brittle matter, which attracting humidity from the air, soon becomes soft. It is dissolved easily by cold water, and still more abundantly by water moderately warm. When the solution is made to boil, it becomes turbid, and coagulates; alcohol added to the cold solution, forms a flocculent precipitate; the acids coagulate it abundantly, and a precipitation is occasioned by a number of metallic salts. The solid matter exposed on burning fuel burns, diffusing an odour similar to that from animal substances. Subjected to destructive distillation, it affords carbonate of ammonia, a thick black oil, carbonic acid, and carburetted hydrogen, a charcoal remaining, difficult of incineration, and which affords phosphate of lime. So far, this substance has all the characters of animal matter; it is farther liable to putrefaction; and, subjected to the action of nitric acid, it affords a large quantity of nitrogen and carbonic acid gases, prussic and oxalic acids being also formed.

The liquid part of the native juice, after the coagulum has separated, appears still to retain a portion of the same principle dissolved; hence it is coagulated by acids and alkohol, and the matter separated is similar in appearance to the white of an egg. Infusion of galls, too, throws down from it an abundant precipitate, properties characteristic of animal albumen. We cannot, observes Vauquelin, by whom this juice was examined, regard without interest a substance produced by a vegetable presenting all the characters of animal matter; and we perceive that nature has given to some plants the power of forming combinations similar to those produced in the animal system.

To the same family with the substances which have been considered under this section, probably belongs the principle denominated CAOUTCHOUC, or Elastic Gum. In physical properties it has resemblances to them, and it agrees with them in approaching in composition to animal matter.

This substance is usually imported from Spanish America in hollow balls; is the inspissated juice of a tree belonging to the family of Euphorbia, the Hævea Guianensis; the juice obtained from incisions is applied in successive layers over a mold of clay; is dried by exposure to the sun, and to the smoke from burning fuel; and when perfectly dry, the mold is broken, leaving the hollow ball. Caoutchouc is not, however, exclusively the product of this vegetable, but is afforded by a number of other plants, natives of the torrid zone, either perfectly the same, or with qualities little different. The juice from which the common caoutchouc is obtained, previous to inspissation, is white; it coagulates speedily from exposure to the air, the coagulum being soft and elastic; alkohol likewise coagulates it, and oxy-muriatic acid throws down an elastic precipitate.

Caoutchouc, in its solid and dry state, is of a close texture, distinctly fibrous, of a light brown colour, or sometimes nearly colourless; its elasticity is such that it can be stretched to a great extent; and on removing the stretch-

-ing force, it recovers its original dimensions; its softness and pliancy are increased by heat; and by the heat of boiling water it is rendered so soft, that two slips newly cut and pressed closely together may be firmly united.

Caoutchouc is insoluble in water; even when the water is boiled on it, it suffers no change but that of becoming softer from the effect of temperature. It is also insoluble in alkohol. Sulphuric ether, however, when highly rectified, dissolves it, and by evaporation the caoutchouc may be recovered unchanged; the solution takes place more readily when it has been previously softened by maceration in warm water. Nitric ether also dissolves it, but produces partial decomposition, probably from the action of the portion of acid usually contained in nitric ether. From the action of the essential oils, aided by heat, solutions are obtained, which remain viscid when inspissated. Even the fixed oils dissolve it when boiled on it.

By the action of the more powerful acids, caoutchouc is decomposed. Sulphuric acid acts very slowly on it, however, unless heat be applied. Nitric acid corrodes and dissolves it, rendering it yellow, and changing its properties. Muriatic or dilute nitric acid has scarcely any sensible effect on it. The alkalis scarcely affect it in the cold, but it suffers corrosion when boiled in an alkaline solution.

Caoutchouc, exposed to heat, softens and swells, emitting an odour similar to that from animal substances; by an increase of heat, it becomes nearly liquid; if the air is admitted, it takes fire and burns with a bright light, and much smoke. Decomposed by heat in close vessels, it affords ammonia with empyreumatic oil, shewing its analogy in composition to animal matter; this is likewise shewn by its affording nitrogen gas and prussic acid when treated with nitric acid.

Caoutchouc, from its softness, elasticity, and impermeability to water, is applied to the formation of catheters, bougies, and tubes for conveying gases. Its solution in oils forms a flexible varnish.

Birdlime is a vegetable product, analogous in its properties both to gluten and caoutchouc, and which may, without impropriety, be associated with them, as not improbably varieties of one species. It resembles gluten in its tenacity, its insolubility in water, and its relations to the alkalis and acids; but it is less animalized, and is therefore not liable to putrefaction. It is still more analogous to caoutchouc in tenacity and elasticity, fusibility, inflammability, insolubility in water, and solubility in ether; and there are varieties of this principle obtained from different plants, less elastic and more viscid than that from the Hævea, which approach therefore very closely to birdlime.

Birdlime exudes from different vegetables, but it is usually prepared from the inner bark of the holly, by boiling the bark in water until it is softened, and then laying it in layers covered with earth and stones; it thus suffers a slow change, and becomes viscid; it is afterwards kneaded and beat, any extraneous matter being removed by washing; and the paste is kept humid for several days to complete the change.

This substance has a greenish colour and slight smell; it is extremely viscid and tenacious, and can only be handled when thoroughly wet; its texture is fibrous, and has such an elasticity that it can be drawn to a great length, from which, when the external force is withdrawn, it immediately contracts. It loses its viscosity when dried, but receives it on the addition of water.

Exposed to heat, it softens and undergoes an imperfect fusion. Placed on burning fuel, it burns with a bright flame, and with a dense smoke.

It is insoluble in water. Alkohol does not dissolve it in the cold, but when boiling a solution is formed, which becomes turbid as it cools, and from which a substance is separated having properties similar to those of wax. Sulphuric ether dissolves it still more abundantly; the solution is decomposed by water, and a quantity of oily matter is obtained.

The acids, if diluted, partly soften, partly dissolve birdlime. Concentrated sulphuric acid chars it, and causes a formation of acetic acid and ammonia. Nitric acid heated on it dissolves it, and as the evaporation proceeds, deposites a hard brittle mass, which, by being subjected anew to the action of the acid, is converted into oxalic and malic acids. Oxy-muriatic acid renders it white, and destroys its viscosity; acetic acid softens and dissolves it. The fixed alkalis decompose it, causing an evolution of ammonia, and the formation of a saponaceous compound, soluble in water and in alkohol, and decomposed by the acids.

Sect. VI.—*Of Wax.*

Wax, though usually obtained as collected by the bee, is a vegetable product. It is secreted by a number of plants, and the wax of the bee was supposed to be collected merely by that insect from the pollen of flowers,—an opinion rendered doubtful perhaps by the experiments of Huber, which prove that bees form wax when all supply of this is excluded, and when they are confined, and fed with honey or sugar alone. Still the existence of wax as a principle of vegetables is fully established. It forms the silvery down sometimes conspicuous on their leaves, flowers, or fruit. The Myrica Cerifera, or Wax Tree, affords in large quantity a product having all its qualities, forming a covering on its seeds; other species of myrica afford the same product, and a number of other plants afford by decoction a similar inflammable concrete.

Wax is solid and brittle, easily softened, however, and acquiring tenacity from a very moderate heat; its colour is usually yellow or greenish, but it can be rendered white by exposure to the air and sun, with a slight degree of humidity, without any change in its qualities.

It melts at 142° of Fahrenheit; myrtle wax is rather more fusible, melting at 109°. It cannot be volatilized without decomposition. The products of this when it is heated in close vessels, are a thick empyreumatic oil in largo quantity, a portion of acidulous water, carburetted hydrogen, and a residuum of charcoal, indicating carbon, hydrogen, and oxygen, as its constituent principles. It burns with a clear and bright flame, affording water and carbonic acid; and from the quantities of these, Lavoisier inferred, that it consists of 80.28 of carbon, with 17.72 of hydrogen.

Wax is insoluble in water. Alkohol scarcely acts on it in the cold; but if boiled on it, dissolves about a twentieth of its weight, the greater part of which is precipitated as the temperature falls. Ether also dissolves it when boiled on it. Myrtle wax is rather more soluble than bees wax in both fluids.

The alkalis, when boiled in solution on wax, dissolve a portion of it, and form an imperfect saponaceous compound, soluble in warm, but sparingly soluble in cold water. Ammonia exerts a similar action. These compounds are decomposed by acids, and the wax recovered from them with its original properties. The myrtle wax is rather more easily dissolved than bees wax.

The acids do not exert much action on wax. Sulphuric acid, when aided by heat, converts it into a mass of a black colour; nitric acid whitens and hardens it.

Wax combines by fusion with the volatile and fixed oils, forming compounds of intermediate consistence. It approaches to the fixed oils in almost all its properties, differing principally in its firmer consistence, its solubility to a certain extent in alkohol, and forming with the alkalis less perfect saponaceous compounds.

Sect. VII.—*Of Fixed Oil.*

There exist two species of oil in vegetables, agreeing in the common properties of unctuosity and inflammability, but essentially different in many of their chemical qualities and relations. The one, from being capable of being volatilized without decomposition, is named Volatile Oil; the other is denominated Fixed Oil. The history of the latter is the subject of this section.

Fixed oils are generally contained in the seeds and fruits of those vegetables of which they are the products, and only at the period of maturity. They are extracted by mechanical pressure,—whence they are named Expressed Oils,—or in some cases by decoction with water. They are frequently impregnated with the mucilaginous or extractive matter of the vegetable, whence they acquire colour, odour, and taste; and if heat has been employed to favour their extraction by expression, they acquire acrimony, and suffer even a change in some of their chemical properties. The purest oils are those expressed from the fruit of the olive, or the seeds of the almond; others less pure are extracted from lintseed, hempseed, and the seeds of other plants.

Fixed oils are usually fluid, but of a thick consistence, and they congeal at very moderate colds; some are even naturally concrete; when fluid, they are transparent, colourless, or of a yellow or green tinge, inodorous and insipid; they are lighter than water; they are incapable of combining with water, and are scarcely sensibly soluble in alkohol.

Expressed oil cannot be volatilized by heat unchanged. At temperatures below 600° of Fahrenheit, they remain fixed; nearly at that temperature, they are converted into vapour; but the oil thus condensed is altered in its properties; it has lost its mildness, and has become more limpid and volatile, a portion of carbon being likewise deposited. Transmitted through an ignited tube, oil is converted into carbonic acid and carburetted hydrogen, with a small portion of acid liquor, and a residuum of charcoal.

Exposed to a warm atmosphere, expressed oils gradually acquire a sharp taste and disagreeable smell, and become thick. This change, named Rancidity, is owing to absorption of oxygen; and hence it takes place sooner when the oil is exposed to oxygen gas, and a large quantity of the gas is frequently absorbed. Drying oils, as those expressed with the aid of heat are named, do not become rancid, but by absorbing oxygen, are rather converted into a resinous kind of matter. By these drying oils the absorption of oxygen is under some circumstances so rapid as to give rise to spontaneous combustion.

At the temperature of ignition, at which it is converted into vapour, oil burns in atmospheric air; a large quantity of light and heat being extricated by its combustion. When the access of the air to the vapour of the oil is not complete, it burns with a black smoke; and a quantity of carbonaceous matter, which has escaped the combustion, is deposited. Hence the utility of a slender wick, which draws up the oil by capillary attraction, and, when kindled, converts it into vapour; and still more of a hollow cylindrical wick, as in the argands lamp, through which an internal circulation of air is established, and the whole oil is consumed; though in this case there is some loss of illumination, from the light from the internal surface having to pass through the flame.

The products of the combustion of oil are water and carbonic acid. 100 parts of oil produce 140 of the former, and 281 of the latter, combining with 321 of oxygen; whence Lavoisier inferred, that oil consists of 79 parts of carbon and 21 of hydrogen, a conclusion which cannot be regarded as more than an approximation; oxygen probably enters into the composition, though in small proportion.

Expressed oil is oxidated by a number of the acids. Sulphuric acid soon renders it black; the oxygen of the acid attracting part of the hydrogen of the oil, and causing the deposition of charcoal; and if heat is applied, a large portion of sulphurous acid is disengaged, and even sulphur is evolved. Nitric acid renders the oil thick and white; if heat is applied, the action is more rapid, and a yellow colour is communicated, the oil being rendered concrete. The drying oils are even inflamed. Muriatic acid exerts little sensible action; oxy-muriatic acid thickens the oil, and renders it white.

Expressed oil combines with the alkalis, and when the combination is perfect, it forms soap. If one part of oil be mixed with half its weight of a strong solution of pure potash or soda, a thick white mass is formed, which can be diffused in water, forming a milky-like mixture.* If the oil and the alkaline solution be boiled gently together, a more intimate combination is effected, and on cooling, a solid compound separates from the liquor. The soap thus prepared, differs according to the purity of the ingredients. Common soap is made of animal oil, or fat, or the coarser vegetable oils with resin; the finer soaps are prepared from olive or almond oil. Potash forms a soap which always remains soft, soda forms one that is more solid and firm. Hence either a solution of carbonate of soda, from which the carbonic acid is abstracted by lime, is employed in the preparation; or if a solution of potash, rendered caustic by the same operation, be used, there is added towards the end of the boiling, a quantity of sea-salt, the soda of which, being in part evolved, has the same effect. The cleansing property of soap depends on its alkali; and although the detergent power of this is weakened by the combination with the oil, advantage is gained from its softness and smoothness, and acting less on the cloth.

Soap is soluble in water, the solution being opaque, from the intermixture of particles of uncombined oil. It is also soluble in alkohol, forming a transparent solution. It is decomposed by all the acids, and by the greater number of the earthy and metallic salts, the acid combining with the alkali, and separating the oil. Hence spring waters often decompose it, from the quantity of sulphate of lime they contain. The oil separated by these decompositions is soluble in alkohol, a proof that, by its combination with the alkali, it has undergone some chemical change. Soap, decomposed by heat, affords water, empyreumatic oil, and ammonia.

Ammonia forms with expressed oil a less intimate combination than the fixed oils do, as heat cannot be employed to favour the combination. The addition of a small quantity of it is employed in pharmacy to suspend oil in water. By adding an ammoniacal salt to a solution of soap, an ammoniacal soap is obtained by double affinity. It is less soluble in water than common soap, and suffers decomposition from exposure to the air.

The combinations of expressed oil with the earths and metallic oxides may be obtained by adding their salts to a solution of soap, when a double decomposition takes place. These compounds have a saponaceous quality, but are in general much less soluble in water than the soap of potash or soda.

Expressed oil, when boiled on sulphur, combines with it, and forms a compound of a brown colour, an extremely fœtid smell, and acrid taste. It likewise dissolves phosphorus with the aid of heat, forming a liquid which becomes luminous when exposed to the air.

Expressed oil promotes the oxidation of some of the metals, as copper or mercury, by the action of the air. It also combines with a number of the metallic oxides. Boiled with oxide of lead, it forms a compound of a firm consistence, what is named in pharmacy Common Plaster.

A mutual action is exerted between expressed oils and several of the other vegetable principles, as gum or resin. Triturated with mucilage, it forms a milky mixture,—a mode of suspending oil in water which is sometimes employed in pharmacy. It melts easily with resin.

Expressed oils, besides their use in pharmacy and medicine, form the basis of paints, being triturated with oxide of lead and the colouring matter. Combined with resins and turpentine, they form varnishes, and printing-ink is a composition of them with lamp black. For some of these uses the drying oils are employed.

SECT. VIII.—*Volatile Oil.*

VOLATILE, or Essential Oil, is contained in the flowers, fruits, leaves, wood, or bark of many vegetables, generally in inconsiderable quantity, the proportion varying, however, according to the age and vigour of the plant. The oil sometimes exists in distinct vesicules, and may therefore be obtained by expression. But the usual method to procure an essential oil, is to subject the vegetable matter containing it to distillation with water. The oil is volatilized with the aqueous vapour, and is easily condensed; a small portion of it is retained in solution by the water; but the greater part separates, and may be obtained pure from the difference in their specific gravity. Being usually lighter, it collects on the surface.

Essential oil is odorous, sapid, and generally pungent, the taste and smell of the oils obtained from different vegetables being very different, and the odour at least is always that of the plant from which they are procured. They are generally lighter than water, but some have a greater specific gravity. They are also usually fluid, and remain so even at a low temperature; but others congeal even at a very moderate degree of cold, and some are naturally concrete. They are volatilized by a very moderate heat. By a strong heat suddenly applied, they are partially decomposed.

Essential oils are soluble in water in minute proportion. The water acquires the taste and flavour of the oil. This impregnation is commonly obtained by distillation, the distilled waters of pharmacy being thus formed. They are much more soluble in alkohol; some of them unite with the alkohol in every proportion, others in limited quantities; and there are even some which are sparingly dissolved. By distilling ardent spirit from vegetables containing much essential oil, distilled spirits are formed.

Exposed to atmospheric air, these oils lose their smell, are thickened, and become concrete, frequently depositing at the same time crystals of an acid nature. These changes are owing to the absorption of oxygen. The acid is similar to the benzoic, and the thickened oil approaches in its properties to resin.

When heated in contact with atmospheric air, they are more easily inflamed than the expressed oils, and burn with a brighter flame, probably from their greater volatility; the products of the combustion are water and carbonic acid, and the water is in larger quantity than from the combustion of the fixed oils. Hence they differ from the fixed oils in containing a larger proportion of hydrogen, to which, probably, their greater volatility and inflammability are owing.

The essential oils are oxidated by the acids. Sulphuric acid renders them black, producing at the same time considerable elevation of temperature, and frequently a violent effervescence from the disengagement of sulphurous and carbonic acid gases. Nitrous acid communicates oxygen with such rapidity as frequently to inflame the oil. By a more slow action it forms prussic, malic, and oxalic acids, and converts the remaining oil into a kind of resinous substance. Oxy-muriatic acid produces a similar resinous matter.

With the alkalis these oils combine with difficulty, and the combination can indeed only be effected by long trituration; the compound is slightly saponaceous. Liquid ammonia distilled with the oil combines with it, but very sparingly.

Sulphur dissolves with the aid of heat in any of the essential oils; the solution has an offensive smell. Phosphorus is also soluble in them, and some of these solutions; that, for example, in oil of cloves, is highly luminous.

These oils unite with mucilage or sugar; and by the medium of either, may be suspended in water. They dissolve resin, camphor, and several other vegetable principles.

In general they are used as perfumes, or in the practice of medicine. Some of them enter into the composition of varnishes.

SECT. IX.—*Of Camphor.*

THIS principle exists in comparatively few vegetables, principally in the aromatic plants. The camphor of commerce is extracted from the *Laurus Camphora*, a native of Japan; the wood of the trunk and branches being exposed to a moderate heat in close vessels, by which the camphor is sublimed. It is at first impure, but is purified by a second sublimation. Camphor is likewise deposited from essential oils when they are long kept, and from some of them, as those of lavender, marjoram, and peppermint, in considerable quantity.

Camphor is solid and tenacious, of a white colour, and semi-transparent; having a strong fragrant odour, and a very pungent taste. It is so volatile, that it quickly loses weight when exposed to the atmosphere; and at a very moderately increased temperature, it sublimes unchanged. If heated under compression, it may be fused.

It is highly inflammable, and burns with a dense light, much smoke, and with a strong smell. Carbonic acid is formed, and a portion of what has been named Camphoric Acid.

Camphor is very sparingly soluble in water, so much being dissolved as merely to communicate a sensible taste and smell. It is abundantly soluble in alkohol; this solution is decomposed by the affusion of water; and if the water be added very slowly, the camphor appears in capillary crystals; a proof that it can assume the crystalline form. It is also dissolved by the essential and expressed oils; and from these solutions the camphor is sometimes deposited in slender crystals.

The alkalis exert no sensible action on camphor. Among the earths, magnesia appears to act on it, as, when they are rubbed together, the camphor becomes smooth, and easily diffusible in water.

The more powerful acids decompose camphor. Sulphuric acid digested on it renders it brown, and dissolves it. When heat is applied, sulphurous acid gas is disengaged; and if the solution is diluted with water and distilled, it affords a little oil, a portion of tannin, which had been formed in the process, remaining in the residual liquor. Nitric acid dissolves camphor, and the solution separates into two liquids, one of an oily appearance, which floats over another more watery; the former contains a portion of camphor, which may be precipitated by water; the latter is acid. When a large quantity of nitric acid is repeatedly distilled from camphor, the decomposition is complete, and a peculiar acid, the Camphoric as it is named, is obtained in crystals, amounting to half the weight of the camphor. Liquid muriatic, fluoric, and acetic acids, dissolve camphor, forming solutions which are decomposed by water; and water, impregnated with carbonic acid, dissolves a larger portion of it than pure water.

When camphor is mixed with any substance which opposes its volatilization, it is decomposed by exposure to heat. Thus, if one part of it be mixed with six parts of pure clay,—if the mixture be dried gently, and reduced to a very fine powder, and then made into small balls with water; when these are completely dried, and are exposed to heat in a retort, a decomposition of the camphor ensues, a volatile oil distils over, a portion of charcoal remains, and a quantity of carburetted hydrogen and carbonic acid gases are disengaged, together with a small portion of camphoric acid. This decomposition points out the nature of camphor: as it is resolved principally into a product having the properties of an essential oil, and into charcoal, or carbonaceous compounds, it may be inferred, that its composition is similar to that of the volatile oils, and that it differs from them principally in containing a larger proportion of carbon.

The Oil of Camphor, obtained by this process, is of a golden yellow colour, has an aromatic odour, somewhat different from that of camphor, and an acrid burning taste. It is volatile and inflammable, entirely soluble in alkohol, and separated from this solvent by the affusion of water.

The acid named the Camphoric, obtained in this process, and also by the action of nitric acid on camphor, appears, from the examination of it by Lagrange, to differ from any known acid. It is obtained in slender crystals, which are sparingly soluble in cold water, but more soluble in hot water. It has no odour of the camphor; its taste is slightly acrid and bitter, and it reddens the infusion of litmus. By a gentle heat it is fused and sublimed, and by a stronger heat is decomposed. It is soluble in alkohol, and likewise in the mineral acids. It combines with the alkalis and earths, forming salts named Camphorates, so unimportant, however, as in an elementary work to require no enumeration.

Camphor appears, in common with some other vegetable proximate principles, to be capable of being artificially formed. By transmitting muriatic acid gas through oil of turpentine, a large quantity of a concrete matter, indistinctly crystallized, is obtained. This, which is at first of a brown colour, becomes perfectly white when washed with water; its odour and taste are the same as those of camphor, with a little of the turpentine flavour, which is, however, removed by sublimation from charcoal and lime. It is volatile, inflammable, soluble in alkohol and in oils, and precipitated by water. The only differences observed between it and natural camphor are in their relations to the acids, artificial camphor not being so easily dissolved. A portion of this substance is obtained from oil of turpentine alone, by a very gentle heat; whence it might be concluded, that, as obtained even by the action of muriatic acid, it pre-exists in the oil; but this is refuted, and the actual formation of it established, by the largeness of the quantity in which it is obtained, seven ounces and a half being procured from a pound of oil.

Sect. X.—*Of Resin.*

This principle, as it exists in vegetables, is often combined with gum, or with essential oil. From some plants, however, it is obtained by exudation nearly pure; or if combined with a portion of essential oil, this may be removed by volatilization, and its characters, in its insulated form, can thus be determined.

Resins, if at first liquid as discharged by the plant, soon become concrete. They are brittle, and have a smooth conchoidal fracture, with peculiar lustre, are more or less transparent, and usually of a yellow or brown colour. Frequently they are odorous and sapid, though others have neither taste nor smell.

They melt at a moderate heat, but cannot be volatilized unchanged. When heated to ignition with the admission of the air, they burn with a dense flame. Heated in close vessels, they suffer decomposition, water, with a portion of empyreumatic acid, much carburetted hydrogen and carbonic acid, and charcoal, being the products. They appear to consist, therefore, of carbon, hydrogen, and oxygen, and probably differ from the essential oils in the inferior proportion of hydrogen.

Resins are insoluble in water, and they suffer no change from the action of the air; hence their adaptation, under the form of varnishes, to prevent substances from being acted on by air and humidity. In a very humid atmosphere, however, they become soft.

They are soluble in alkohol, and likewise in ether, these solutions being decomposed by the affusion of water. They are also dissolved by essential and expressed oils, and the chemical action of camphor on them is marked by its rendering them quite soft, and nearly liquid.

The fixed alkalis dissolved in water, digested on resins, dissolve them, and even in the state of carbonate, or in that of compound salts, with a slight excess of alkali, exert this solvent power. The action of ammonia is more weak.

The more powerful acids decompose resinous matter. Sulphuric acid at first dissolves it, but, continuing to act upon it, progressive changes of composition take place, tannin is formed, and ultimately the residual matter is carbonaceous. Nitric acid produces at first decomposition, the resinous matter being converted first into a substance having characters intermediate between resin and extract, and by farther changes into a variety of artificial tannin. Acetic acid dissolves resins, apparently without altering their composition.

A number of resinous substances are employed in medicine, or in the arts,—such are copal, mastich, sandarach, animi, and the resins from the juice of the different species of pine. These have the same chemical properties, or with differences comparatively so unimportant, as not to require particular enumeration. A peculiarity of mastich is, that it is not entirely soluble in alkohol, and the part which remains undissolved approaches in its characters to caoutchouc, being glutinous and elastic. Copal, too, is more sparingly soluble in alkohol than the others, forming rather a kind of viscous mass; camphor renders it completely soluble. Sandarach and elemi are partially soluble in oils.

Resins are employed in the formation of varnishes, being dissolved either in alkohol, or in essential or expressed oils. The former are named Spirit Varnishes; they dry quickly, but have the disadvantage of being liable to scale; and to obviate this, by giving a degree of tenacity, a portion of an essential oil, as that of turpentine, is often added. The latter dry more slowly, and are liable to remain a considerable time clammy. The essential oil employed is usually that of turpentine; the expressed oil that of lintseed, rendered drying by having been expressed by heat; and these are often mixed together. Copal forms the basis of the finer varnishes, but there is considerable difficulty in dissolving it; the addition of a little camphor best promotes its solution, either in oils or in alkohol.

The name of GUM-RESIN has been applied to a number of substances which have long been employed in the practice of medicine, and which, from the action of solvents on them, appear to be compounds of gum and resin, in different proportions;—such are, aloes, assafætida, ammoniac myrrh, and others. They are solid and usually brittle, have often a strong taste and smell, and exert considerable activity on the animal system. Their chemical properties appear to be those of their immediate principles, gum and resin, slightly modified; they are usually insoluble either in water or alkohol; those in which gummy or extractive matter predominates, as aloes, are more completely dissolved by water; and those in which resin is more abundant, as myrrh, are dissolved more easily by alkohol; they are in general dissolved by alkohol diluted with one or two parts of water. Alkaline solutions dissolve them; acids decompose them; and in these decompositions they are not so easily converted into artificial tannin, as the pure resins. They are decomposed by heat, and with the usual products of the decomposition of vegetable matter, afford a portion of ammonia.

A substance which used to be ranked as a gum-resin, Guaiac, appears, from the observations of Mr Brande, to have some peculiar properties. It displays in particular striking changes of colour from the action of oxygen, and of the acids; its solution in alkohol yielding, when decomposed by oxy-muriatic acid, a precipitate of a beautiful pale blue colour; when decomposed by sulphuric acid, one of a pale green colour; and from the action of diluted nitric acid a liquid is obtained, which is at first green, afterwards blue, and brown, and affords precipitates of the same colour, on the addition of water. In the direct action, too, of the acids on guaiac, changes of colour are produced,—sulphuric acid forming a solution of a deep-red colour, and nitric acid producing a deep green tint; the nitric acid is rapidly decomposed, and oxalic acid, with a substance more completely resinous, are obtained.

Balsams are vegetable products, which consist chiefly of resinous matter, with essential oil, but which afford, also, when submitted to different processes, a portion of a peculiar acid, the Benzoic; and the presence of this acid gives the peculiarity of composition which is hence supposed to constitute a balsam.

Their chemical properties are, of course, derived from the principles of which they consist. They are insoluble in water, but abundantly soluble in alkohol, their solutions being decomposed by the addition of water,—from the precipitation of their resinous matter. By distillation with water, they afford, in general, a small quantity of essential oil. The acid is extracted from them, either by applying a gentle heat, when it is volatilized; or by maceration in water, when it is dissolved; or, lastly, by boiling them with an alkali or earth with which the acid unites, and from which it may be afterwards separated by the addition of another acid.

The principal balsams are those of Tolu and Peru, as they are named, Storax and Benzoin, the latter being concrete, the former fluid, but thick, and even becoming solid from age; they are odorous and pungent, and are regarded principally as articles of the materia medica.

SECT. XI.—*Of Extract, or Extractive Matter.*

BY expressing the juices of recent herbs, or by boiling the leaves, bark, or wood of vegetables, and evaporating, in either case, the liquor to a thick consistence, preparations are obtained, which, in pharmacy, have been long known by the name of Extracts. It is obvious that these may consist of various proximate principles, which the water has dissolved. But it has likewise been supposed, that a peculiar principle generally forms the basis of them.

This has accordingly been distinguished by the appellation of Extract; and distinctive properties have been assigned to it. Of these it is necessary to take notice, though the existence of this as a peculiar principle, I shall have to remark, is liable to much doubt.

Extract is said to be soluble in water, but to become gradually insoluble from exposure to the air, especially at a high temperature. Vauquelin has remarked, that the juices containing it are colourless, as they exude from the plant, but that they become yellow or brown from exposure to the air. If evaporated, pellicles soon form on its surface, and the solid matter procured by continuing the evaporation, cannot be again entirely dissolved in water. Fourcroy likewise has observed, that the decoction of a vegetable which affords extract becomes turbid as it boils; the precipitated matter cannot be dissolved by an addition of water; and the longer the boiling of it is continued, and the more freely the air is admitted, the larger is the quantity of it formed. He concludes, therefore, that the insolubility is the consequence of the oxygenation of the extractive matter, and the facility of combining when it is in a humid state with oxygen, has been assigned as a character of this principle. Saussure, in exposing solutions of extractive matter to atmospheric air in close vessels, found the oxygen of the air to be consumed, and an equivalent portion of carbonic acid formed, while precipitates had been deposited from the liquors. He inferred, that in thus losing a portion of carbon by combination with the oxygen of the air, part of the oxygen and hydrogen of the extractive matter likewise combine to form water, and that the residual matter has thus an enlarged proportion of carbon. It is quite insipid and inert, and the loss of power which many active medicinal plants sustain by boiling in water, without any volatile principle being dissipated, has been ascribed to these changes in the extractive matter in which their powers are supposed to reside.

Extract is soluble in alkohol, and the solution is not decomposed by water. This property of equal solubility in water and alkohol, and that which follows from it, of the solution in the one fluid not suffering decomposition from the other, has been assigned as another character of this principle not belonging to any other—gumresin, which approaches nighest to it in this respect, being only partially soluble in either, and its solution in the one in which it is most largely dissolved being decomposed by the other.

Oxy-muriatic acid converts extractive matter into a concrete substance of a deep yellow colour, insoluble in water, but soluble in alkohol, and in alkaline solutions.

Argil exerts an affinity to it, and forms an abundant flocculent precipitate with it from infusions in which it is dissolved. Several metallic salts have a similar effect, in consequence of the affinity between extractive matter and metallic oxides.

Extractive matter, in the spontaneous decomposition which it suffers in a humid state, exhales ammonia, and this alkali in part saturated by acetic acid, is afforded by it when it is decomposed by heat.

In reviewing the characters assigned to this principle, and the facts connected with its chemical history, there is room to doubt if its existence is fully established. There is no process by which we can be certain of having obtained it in an insulated state; as it exists either in vegetable juices, or as obtained by decoction from any of the parts of plants, it necessarily must be in a state of intermixture, and the properties assigned to it, therefore, may merely arise from modifications produced by such intermixture in other known principles. Some of these properties, too, such as that of absorbing oxygen when in a humid state, or of exerting an affinity to argil or metallic oxides, belong to other principles. And what further throws doubt on the opinion which regards it as a distinct principle, is that even the properties assigned as characteristic of it are not uniform, the facility of decomposition, when in a humid state, from the action of oxygen, being sometimes for example possessed by a variety of extractive matter, without the equally distinctive quality of equal solubility in water and in alkohol.

Sect. XII.—*Of Tannin.*

The property of astringency in vegetables is indicated by a peculiar styptic taste, and by the power of corrugating the animal fibre, displayed in the operation of tanning. A peculiar chemical phenomenon had also been discovered to be connected with it, which hence came to be regarded as its test, that of producing a dark purple colour with the salts of iron, the power of producing this belonging to all the vegetable astringents, and nearly in proportion to their astringency. It was afterwards discovered that a peculiar acid exists, in the more powerful vegetable astringents, and which in particular being abundant in galls, received the name of Gallic Acid. This acid, it was further found, struck the same dark colour with the salts of iron; hence it was concluded to be the principle common to astringents, and that on which their astringency depends.

An evident objection, however, to this opinion was, that the acid itself has no great degree of astringency; it was further found, that the colour it produces with the salts of iron is much less deep than that produced by the infusion of a vegetable astringent, a proof that some other substance exists in the infusion, on the action of which the production of the colour, in part at least, depends. Another principle has been accordingly discovered, which is rather to be regarded as the principle of astringency. Being the chief agent in the operation of tanning, it has received the name of Tannin, and for its discovery we are indebted to Seguin. The experiments by which he established its existence, consist in adding to the infusion of a vegetable astringent, as of galls or oak-bark, a solution of animal gelatin, as of glue or isinglass. A copious precipitate is immediately formed, which consists of the gelatin in combination with tannin; the gallic acid, mucilage, or any other principle contained in the astringent, remaining in the liquor above.

By this process tannin is not obtained in an insulated state; and though various methods have been employed, it is not very certain if any of them afford it perfectly pure. The simplest is to add lime-water to an infusion containing tannin; a precipitate is formed which consists of the tannin combined with lime; and if this be treated with diluted nitric or muriatic acid, the lime is abstracted, and the tannin remains. Another is, to add sulphuric acid to a strong infusion; a precipitate is thrown down, consisting principally of tannin combined with the acid; it is dissolved in boiling water, and the acid is abstracted by the addition of an alkaline carbonate, the tannin being precipitated if an excess of water is not present.

Tannin, by evaporation of its solution, may be obtained in the solid form. It is friable, has a resinous-like fracture, is of a brown colour, or, according to Lagrange, a white colour, which becomes brown from the action of the air; its smell is peculiar, and its taste rough and bitter.

It dissolves in cold water, but more abundantly when the temperature is raised. It dissolves in alkohol of the usual strength, but, according to Richter, is insoluble in alkohol highly rectified.

From the observations of Seguin and Lagrange, it appears in its humid state to be very susceptible of oxygenation. When its solution is exposed to the air, pellicles form on its surface from this cause, and a similar change is produced by exposure to oxygen, or to oxy-muriatic acid gas. By oxygenation it acquires, according to Lagrange, the power of reddening infusion of litmus. It is little liable, however, to spontaneous decomposition, and is even a powerful antiseptic.

Tannin is precipitated from its solutions by the acids, combinations of the acid, and the tannin being established in different proportions, one forming an insoluble compound, and another one which is dissolved. Nitric acid, after precipitating the tannin, if concentrated, re-acts on it, and decomposes it. Oxy-muriatic acid, according to Lagrange, converts it into gallic acid.

The alkalis combine with tannin; a solution of potash or soda, first precipitates it, but soon re-dissolves it, and suspends its powers of combining with gelatin. Ammonia forms apparently a less soluble compound. The alkaline carbonates have nearly similar effects. Lime, barytes, strontites, and magnesia, form with it compounds of sparing solubility; and similar combinations are established even when the carbonates of these earths act on an infusion containing it, so that the tannin is entirely precipitated.

Tannin appears to exert strong attractions to the metallic oxides. Precipitates are thrown down from the greater number of metallic salts by the infusion of galls, which appear in general to consist of the oxide, the base of the salt united with tannin. These combinations are even established by boiling the infusion on the pure oxide; and by oxide of tin or zinc the whole tannin is thus abstracted. The most important combination of this class is that with oxide of iron. It is in consequence of its formation, that the infusions of the vegetable astringents strike so deep a colour with the salts of iron; for although the gallic acid is often associated with tannin, and gives a similar colour, it does so much more faintly, and the intensity of the colour depends chiefly on the tannin. The iron requires to be in a certain state of oxidation for its production, the colour being faint when it is at the *minimum*, while, if more highly oxidated, it is deep; a difference owing partly perhaps to the relation of the oxide itself in these different states to tannin, but partly also, as has been already explained, to the difference in the force of affinity with which it is retained in combination by the acid of the salt, the affinity being weaker at a high than at a low state of oxidation, and hence the combination of the oxide with the tannin being more easily effected. The acid of the salt re-acts on this compound, and in some measure retains it dissolved. This combination is the basis of writing-ink, and of the black dyes. The essential ingredients of the former are infusion of galls and sulphate of iron; by their mutual action the compound of tannin and oxide of iron is formed, which the gallic acid of the infusion, and the sulphuric acid of the salt, contribute to hold suspended or partially dissolved; a portion of gum is added, to give sufficient consistence to the liquid, and frequently a little sugar to give the ink lustre. The decay of ink from age is probably owing to the decomposition of the tannin from the slow but continued action of the metallic oxide and the sulphuric acid on it. In the formation of the black and purple dyes, different astringents are employed, besides the gall-nut, particularly the bark of some species of willow, logwood, and sumach.

The most important and characteristic chemical property of tannin, is that displayed in its relation to animal gelatin. They combine with much facility, forming from a state of solution a soft flocculent precipitate, which on drying becomes hard and brittle. The tannin of different vegetables combines with different proportions of gelatin. The combination is influenced, too, with regard to the relative quantities that combine, by the concentration of the solution of gelatin, the quantity of precipitate being greater when the solutions are mixed in a concentrated state; and also by the quantity in which one is added to the other, an excess of gelatin re-dissolving part of the precipitate, or rather forming with the tannin a more soluble compound.

On the formation of this combination depends the art of tanning. The skin of an animal, when freed from the hair, epidermis, and cellular fibre, (which is done in the manipulations of the art, principally by the action of lime), consists principally of indurated gelatin. By immersion in the tan-liquor, which is an infusion of oak-bark, or other powerful astringents, the combination of the tannin with the organized gelatin, which forms the animal fibre, is slowly established, and the compound of tannin and gelatin not being soluble in water, and not liable to putrefaction, the skin is rendered dense and impermeable, and not subject to the spontaneous change which it would otherwise soon undergo. To render it equal throughout the whole substance of the skin, the action of the tan-liquor must be gradual, and hence the tanning is performed by successive immersion of the skin in liquors of different strength. A portion of the extractive matter of the infusion appears also to enter into the combination. The skin increases in weight from one-fifth to one-third.

Tannin decomposed by heat affords an acid liquor, a brownish oil, and a considerable quantity of carbonic acid, a light spongy charcoal forming the residuum.

An important fact in the chemical history of this principle, is its artificial formation. It had been known to be developed by heat, in substances in which it did not previously exist. Mr Hatchet observed, that it is produced in the action of nitric acid on carbonaceous compounds; and extending his experiments, he has shewn, that it is formed in the action of sulphuric and nitric acid on resins, gum-resins, bituminous substances, and many other varieties of vegetable matter, and even from a number of animal substances. Those which were carbonaceous yielded it most readily; hence in many of them the previous operation of charring favoured the production of tannin; from the same action sulphuric acid produced it more readily than nitric acid, or the previous action of sulphuric acid favoured its production by the action of nitric acid; or, lastly, if nitric acid alone were employed, it required, with regard to a number of substances, to be used in large quantity, and to be repeatedly distilled from them. The product obtained by all these operations has the general qualities of tannin; its taste is astringent, it combines with gelatin, and its relations to other chemical agents are similar to those of this principle. Mr Hatchet observed, however, that it differs somewhat in its properties as produced in these processes, and he has marked three varieties of artificial tannin:—the *first*, formed by the action of nitric acid, approaching nearest to natural tannin, and differing from it only, indeed, in not being decomposed by the continued action of nitric acid: the *second*, formed by the repeated distillation of nitric acid from vegetable resins, gum-resins, and balsams, and differing from the other in the colour of the precipitates it forms with gelatin: the *third*, produced by the action of sulphuric acid on the same substances, less energetic in its action on gelatin and skin, and therefore most remote from natural tannin. These differences probably depend on slight differences in the composition which constitutes this principle. Nitrogen does not appear to enter into the composition of the last variety, to which he supposes its less powerful action may be owing.

Proust remarked, that even natural tannin is not uniform in its qualities, but differs as afforded by different vegetables, whence he concluded that there are varieties of it, as there are of several other vegetable proximate principles. Mr Davy suggested, that such differences might arise from the presence of other principles capable of modifying the action of tannin, and stated some facts in proof of some of these peculiarities depending on this cause. It is not improbable, however, that slight variations in the composition may in natural, as well as in artificial tannin, produce diversities of properties.

The analysis of the principal astringents was undertaken by Mr Davy, with the view of determining the proportion of tannin they contain. Galls contain it in largest quantity. Oak-bark affords a less proportion, from the predominance of the ligneous fibre. Catechu yields about half its weight of it, and kino appears to contain even a larger proportion. In the greater number of these, the tannin has been supposed to be combined principally with mucilage and extract, a supposition, however, which Dr Bostock has rendered doubtful. Tannin is generally accompanied with a portion of gallic acid, but this acid has been supposed to be often present in vegetables, without any sensible quantity of the tanning principle.

A principle exists in some vegetables, which appears to have some relation to tannin, the nature of which is not yet well understood. It has the character of forming with tannin an insoluble precipitate, whence Seguin supposed it to be analogous to animal gelatin, a supposition which has no probability, as Dr Duncan has shewn. From its existing in several of the species of cinchona, he has given it the name of Cinchonin.

SECT. XIII.—*Of Gallic Acid.*

THERE exist in the juices of many plants, at certain periods of their vegetation, peculiar acids, and the same or other acids are likewise found combined with some of the vegetable proximate principles, or united with alkaline or earthy bases, forming what have been named the Essential Salts of Plants. Of these native vegetable acids, seven have been usually enumerated, the Gallic, Malic, Citric, Oxalic, Tartaric, Benzoic, and Acetic. There may be added to the number, the Moroxylic, an acid of later discovery, and the Prussic, though the latter has been more usually ranked among the substances belonging to the animal kingdom. These acids have a compound base of carbon and hydrogen, and differ principally in the proportions of their elements; hence they are convertible into each other. The oxalic appears to be the one most highly oxygenated, and it is it into which the greater number of the others are ultimately changed.

Gallic Acid, the first of these, and the history of which is to be given under this section, has an intimate connection with tannin; they are generally associated in the vegetable astringents, and they are similar in some of their most striking chemical relations. It derives its name from the gall-nut, in which it exists in large quantity, and from which it is usually obtained. Its presence is shewn by the power which the infusion of galls has in reddening litmus; and it may be procured by a process given by Scheele,—merely allowing a strong infusion to remain in a vessel imperfectly inclosed for some months; a sediment is deposited; this being washed with cold water, and dissolved in boiling water, crystals of a greyish colour are procured, which are acid. Scheele observed, too, that by distillation galls afford an acid liquor, and a portion of a concrete acid is condensed in a crystalline form. Other methods have been employed, such as abstracting the tannin and extract of the infusion of galls by the affinity of argil, or boiling in the infusion carbonate of barytes, and decomposing the gallate of barytes by sulphuric acid.

But it is not certain, if by either of these processes the acid is obtained in a state of purity, and in particular altogether free from tannin: this principle always adheres, too, to the acid procured by the first process of Scheele, so as to render it capable of precipitating gelatin. There remains, therefore, only the process of sublimation, and this probably gives the gallic acid in its purest state, a minute portion of oily matter only adhering to it, which gives it a slight aromatic odour; it gives no precipitate with gelatin, and therefore does not appear to have any intermixture of tannin. It is inferior, however, to the acid procured by the spontaneous decomposition of the infusion of galls in acid powers, a difference which Lagrange considers as owing to the latter having combined with it a portion of acetic acid. With regard to the different states of this acid, and its purity, there still remains, on the whole, considerable uncertainty.

The sublimed acid is procured in crystals of a white colour, if the heat has not been raised too high, or continued too long, so as to volatilize any vegetable matter, which gives it a brownish tinge. When purified too by solution and crystallization, the acid is white; its crystals are slender prisms, its taste is sour; it reddens, though not very deeply, the vegetable colours, and excites effervescence in the alkaline carbonates; it requires 24 parts of cold water for its solution, but dissolves in less than 2 parts of boiling water, this solution crystallizing on cooling. It dissolves in 4 parts of alkohol, at a medium temperature.

Exposed to heat it fuses, exhaling an agreeable odour;

a portion sublimes, and condenses in crystals, while a quantity of acid liquor is also produced, a large quantity of charcoal remaining in the retort. The concrete acid has nearly the same taste and odour as acid of benzoin. The products of its entire decomposition prove it to be a compound of carbon, hydrogen, and oxygen. By nitric acid it is converted into oxalic acid.

Gallic acid combines with the alkalis and earths. Its salts are named Gallates; they have been little examined: those, with the alkalis, are soluble; they throw down dark-coloured precipitates from metallic solutions, similar to those produced by the acid itself.

This property of forming dark-coloured precipitates with the solutions of metals, is the most important one belonging to gallic acid, as rendering it a re-agent of considerable delicacy. The observations with regard to these, however, are of less value, as the acid has been usually employed in that state in which it has an intermixture with tannin; and we have no accurate comparative experiments with regard to the effects from it in a purer form. Its action on the salts of iron has been principally examined, and this is similar to that exerted by tannin. It strikes a violet or purple colour, more or less deep; but for the production of the colour, the iron requires to be in a high state of oxidation; hence, if added to a solution containing the iron at the minimum of oxidation, no colour is immediately produced; but it soon appears from exposure to the air, probably from oxygen being absorbed. It can also be rendered apparent, however, by causes which cannot change the state of oxygenation, as by dilution with water, or the addition of a little alkali; and hence probably the reason of its not appearing when the salt contains the iron imperfectly oxidated, is, that the oxide in that state is retained by a stronger attraction in combination with the acid with which it is united, than when the oxidation is more perfect. The colour, from the action of gallic acid, is less deep than that from tannin; and the precipitate is much finer, and remains longer suspended. Perhaps there is some reason to suspect, that the colour is always produced by tannin adhering to the acid, and that the acid, only by its re-action on the precipitate, brings the compound more nearly to a state of solution.

From this relation subsisting between gallic acid and tannin on oxide of iron, arises the advantage derived from their combination, in the formation of writing ink, or black dyes, or the superiority of the infusion of a vegetable astringent, in producing the colour, to either of them in its separate state.

Sect. XIV.—*Of Malic Acid.*

The juices of unripe fruit are in general sour, and this is owing principally to the presence of an acid, which being abundant in the unripe fruit of the apple, has been named Malic Acid. It exists in many other unripe fruits, particularly in the plumb, sloe, barbery, gooseberry, and currant, mixed more or less with another acid, the citric. To obtain it pure, the juice containing it is neutralized by carbonate of potash, to the saturated liquid acetate of lead is added; the malate of lead which is precipitated, is washed with water, and is then decomposed by sulphuric acid. This acid is also artificially formed in the action of nitric acid on fecula, sugar, and other vegetable principles, and is separated from the oxalic acid, generally formed in the same processes by the addition of lime-water, which forms with the oxalic acid an insoluble compound, with the malic acid one that remains dissolved.

Malic acid, however far its solution may be evaporated, does not crystallize, a property by which it is distinguished from the other vegetable acids. It acquires a brown colour, and becomes thick; its taste is extremely sour, and it reddens strongly the vegetable colours. It suffers spontaneous decomposition. It is also decomposed by heat, affording the usual products of the decomposition of vegetable matter, and in particular a large proportion of carbonic acid gas. It is charred by sulphuric acid. By nitric acid, it is converted into oxalic acid.

This acid combines with the alkalis and earths, forming salts denominated Malates. The alkaline malates are soluble and deliquescent, and even the earthy malates have more solubility than the salts formed by the earths with the other vegetable acids; by a slight excess of acid, they are in particular rendered quite soluble.

Malic acid acts on those metals which have a strong affinity to oxygen, and combines with the oxides of the others, and in consequence of this, decomposes several metallic salts.

SECT. XV.—*Of Citric Acid.*

THIS acid exists in the lime, the lemon, the tamarind, and many other sour fruits. It may be obtained from them by expression, the acid juice being diluted with alkohol, by which the mucilaginous matter is precipitated, and the alkohol being then evaporated; but the purification by this method is not complete. According to the process given by Scheele, the expressed juice of the lemon, after filtration, is neutralized by carbonate of lime. The citrate of lime thus formed is insoluble in water; it is washed to carry off any remaining mucilage, and is decomposed by adding half its weight of sulphuric acid, diluted with six parts of water, the action being promoted by a gentle heat. The sulphate of lime is precipitated, the citric acid remains dissolved, and by evaporation may be obtained in a crystalline form. The crystallization is more easily effected when a slight excess of sulphuric acid has been added. If the acid is coloured brown, it may be obtained white by a second crystallization.

Its crystals are rhomboidal prisms; they are permanent in the air, or slightly efflorescent; they are soluble at a moderate temperature, in little more than their own weight of water, and in half their weight of boiling water; the solution has a strongly acid taste, and reddens deeply the vegetable colours.

Citric acid, exposed to heat, is decomposed, affording carburetted hydrogen, carbonic acid, and empyreumatic acetic acid, with a residuum of charcoal. Its constituents therefore are, carbon, hydrogen, and oxygen.

This acid is not, like several others, convertible into oxalic acid; but, when decomposed by the nitric or sulphuric acid, is changed partly into acetic, partly into carbonic acid.

Citric acid combines with the alkalis and earths, and metallic oxides; citrate of potash is soluble, deliquescent, and does not easily crystallize; citrate of soda is likewise very soluble, but crystallizes readily in six-sided prisms, which are efflorescent; citrate of ammonia also crystallizes, though with difficulty, in elongated prisms. The earthy citrates are much less soluble. The metallic citrates are not sufficiently important to require notice.

SECT. XVI.—*Of Oxalic Acid.*

THIS acid exists abundantly in the juice of the leaves of the sorrel, (oxalis acetosella), combined with a portion of potash not sufficient to neutralize it. This salt, the super-oxalate of potash, is obtained by expressing the juice, allowing the impurities to subside, and clarifying it more completely by boiling it with water, in which a small portion of fine clay is suspended. After due evaporation, the salt crystallizes, and is purified by a second crystallization.

From the super-oxalate of potash the oxalic acid may be procured, according to the process given by Scheele, by adding to its solution acetate of lime, as long as there is any precipitation; the oxalate of lead, being washed, is decomposed by sulphuric acid, which combining with the oxide of lead, the oxalic acid is disengaged. This acid can also be formed by an artificial process; and as this is easily conducted, it is more frequently obtained by it than from the native salt. The process consists in oxidating sugar by nitric acid. One part of refined sugar in powder is put into a retort with three parts of nitrous acid; a strong mutual action is exerted, and nitrous acid vapours are disengaged; when this has ceased, an additional portion of acid is added, and a moderate heat applied; the liquor, on cooling, affords a large quantity of oxalic acid, crystallized in slender prisms. The uncrystallizable liquid, which contains malic acid, being removed, the crystals are purified by solution, and a second crystallization. The acid is in this process formed not merely from the oxygenation of the sugar by the nitric acid, but from more complicated changes of composition not well determined. It is obtained, by a similar process, from fecula, gum, and several other vegetable products.

Oxalic acid crystallizes in slender four-sided rhomboidal prisms; the crystals, when pure, are white and transparent. Their taste is sour, and they redden deeply the vegetable colours. They are soluble in twice their weight of cold water, and in an equal weight of boiling water. They are also soluble in alkohol.

Exposed to heat, oxalic acid suffers decomposition. The products are an acid liquor, with a quantity of concrete acid, which condenses in the neck of the retort, and which is the oxalic acid extremely pure; much carbonic acid, and carbonic oxide, or carburetted hydrogen gases, are disengaged; there is scarcely any empyreumatic oil; it may be inferred, therefore, that there is little hydrogen in the composition of this acid, that it contains a large proportion of carbon, and, probably from its being formed from the other vegetable acids by processes communicating oxygen, that it contains also a considerable portion of this element. It suffers decomposition from the action of the more powerful acids.

This acid exerts affinities of considerable strength to the alkalis and earths. Its salts are named Oxalates. Oxalate of potash, if neutral, is not easily crystallized, but with even a slight excess of acid, readily assumes a crystalline form, and the native super-oxalate may be obtained in crystals of considerable size, white, permanent in the air, and abundantly soluble in water. Oxalate of soda, when neutral, is much less soluble; but with an excess of acid, is more soluble, and more disposed to crystallize. Oxalate of ammonia is abundantly soluble when neutral, and with a slight excess of acid, is obtained, by slow evaporation, crystallized in quadrangular prisms. The earthy oxalates, with the exception of oxalate of argil, are of very sparing solubility. The acid appears to exert a strong affinity to lime, attracting it from any other acid, as the lime, on the other hand, attracts the oxalic acid from any other salifiable base; and the compound being of very sparing solubility, its formation affords a very delicate test, either of lime, or of the acid itself. The metallic oxalates present no fact of any interest with regard to their history.

Oxalic acid is principally employed as a test of lime.

The native super-oxalate of potash, under the name of Salt of Lemons, is used to remove ink-stains, an effect which it produces by dissolving the oxide of iron, which, with tannin, forms the colouring matter of ink.

SECT. XVII.—*Of Tartaric Acid.*

THIS acid, as it exists in vegetables, is usually combined with potash, forming a salt with an excess of acid,—the super-tartrate of potash. This is deposited in considerable quantity from the juice of the grape during its conversion into wine, or rather from the wine during the slow fermentation it suffers in the cask. It does not appear to be a product of the fermentative process, but pre-exists in the juice of the grape, and is merely separated. It also exists in other fruits, as in the tamarind, of which it forms a considerable part. As first deposited from wine it is impure, having associated with it colouring matter, and tartrate of lime. In this state it forms the Crude Tartar of commerce, named White or Red Tartar, according to its colour. It is purified by boiling it in water, with the addition of a small quantity of fine clay, which attracts the colouring matter. By evaporation it is obtained crystallized, forming the Purified Tartar, Crystals, or Cream of Tartar of the shops.

From this salt the tartaric acid is obtained. The process of Scheele, which is the best, consists in adding to a solution of the super-tartrate of potash in boiling water, carbonate of lime in powder, as long as any effervescence is excited; the tartrate of lime which is formed and precipitated, being well washed, is decomposed by adding sulphuric acid equal in weight to the chalk that had been employed, previously diluted with half its weight of water, digesting them with a moderate heat; the sulphuric acid combines with the lime, and forms the sulphate, which being of sparing solubility, is separated, while the tartaric acid is dissolved by the water, and by evaporation is obtained in a crystallized form.

The crystals of this acid are usually tabular, sometimes also prisms, white and nearly transparent; their taste is very sour, and they redden deeply the vegetable colours. They are very soluble in water, and form a solution so concentrated as to have an oily appearance.

Tartaric acid is decomposed by heat; it affords a large quantity of empyreumatic acetic acid, with a portion of empyreumatic oil, much aerial fluid, consisting of carbonic acid and carburetted hydrogen, and a bulky charcoal.

It combines with the alkalis and earths, forming salts, properly named Tartrates, though from this acid having the name of Tartarous given to it, they are often denominated Tartrites. The acid appears to have a peculiar tendency to enter into simultaneous combination with more than one base, and to form ternary salts, which crystallise with much regularity, and are of uniform composition.

Tartarate of potash is usually formed by neutralizing the excess of acid in the super-tartrate, by the addition of carbonate of potash. From its affinity to water, it is not easily obtained crystallized; by slow evaporation, however, in a dry atmosphere, crystals in the form of tetraedral prisms are procured. It is deliquescent in a humid atmosphere, and very soluble in water, whence its name of Soluble Tartar. It is very susceptible of decomposition, so far as relates to the abstraction of that portion of alkali which renders it neutral, and hence it is converted by the action even of weak acids into the super-tartrate. This super-tartrate is of more sparing solubility,—requiring 60 parts of cold and 30 of boiling water for its solution. It concretes from the latter solution in small irregular crystalline masses, white and semi-transparent. Its taste is sour. It consists of 57 of acid and 33 of potash, with 7 of water. It is decomposed by heat, and, from the decomposition of the acid, is converted into carbonate of potash.

Tartrate of soda is soluble and crystallizable; a triple salt, the Tartrate of potash and soda, formerly named Rochelle Salt, is formed by neutralizing the excess of acid in the super-tartrate, by adding carbonate of soda. It crystallizes in regular rhomboidal prisms. Tartrate of ammonia is a very soluble salt. The tartrates of barytes and lime are insoluble; those of magnesia and argil do not crystallize, their solutions becoming gelatinous on evaporation.

Tartaric acid acts on some of the metals, and it may be combined with the oxides of all of them by double affinity. From the excess of acid in the super-tartrate of potash, it dissolves several of the metals or their oxides; and from the tendency of this acid to establish ternary combinations, the compounds thus formed are often of uniform composition. The most important of them is that formed with oxide of antimony, the preparation and properties of which have been noticed under the history of that metal.

SECT. XVIII.—*Of Benzoic Acid.*

THIS acid exists in the natural balsams, in combination with resin and essential oil, and is obtained from them by the application of a moderate heat,—from the one named Benzoin in largest quantity, whence its name; it rises in vapour, and condenses in slender prisms. It can also be extracted by boiling the benzoin in water, or in larger quantity, by boiling it with a portion of slaked lime, and decomposing the benzoate of lime which is formed, by adding to the liquor when cold muriatic acid; the benzoic acid is precipitated. In all these cases the benzoic acid appears to be merely extracted from the balsam in which it exists, and not formed, as some chemists have supposed; for it is not very probable that the formation of a substance perfectly uniform as obtained by these processes, should be determined by operations so dissimilar; and the chemical agency of some of them, of water for example, appears not to be sufficiently powerful to *cause* its formation. This acid is not only a vegetable product, but belongs also to the animal kingdom, being sometimes found in the urine of gramenivorous animals; also in that of children; and in general, indeed, when the phosphoric acid of that secretion is deficient.

Benzoic acid is, according to the usual method in which it is obtained, in soft light flakes, or in slender needle-like crystals; when pure, white and brilliant. Its taste is pungent, and slightly acidulous. It has a peculiar odour, somewhat aromatic, which becomes strong when it is heated and volatilized. This appears not to be essential to it, but to be derived from a small portion of oily matter derived from the balsam.

This acid is fusible; and when it has become solid after fusion, its surface exhibits a stellular radiated appearance. It is also volatile. Heated on burning fuel, it inflames. Urged with a strong fire in close vessels, the portion that is not immediately sublimed is decomposed, and affords an acid liquid, a quantity of oil more abundant than what is produced in the decomposition of any other vegetable acid: carburetted hydrogen is also disengaged in a considerable proportion, and charcoal is left in the retort. It consists, therefore, of the usual principles of vegetable matter, and, compared with the other vegetable acids, hydrogen predominates in its composition.

It is scarcely soluble in cold water, but is abundantly soluble in hot water. Its hot solution reddens the infusion of litmus. Alkohol dissolves it abundantly; and it is precipitated from this solution by the addition of cold water.

Benzoic acid is not easily decomposed by the mineral acids; they dissolve it, but it is precipitated again by water little changed.

This acid unites with the alkalis and earths, forming salts denominated Benzoates; their properties are not important, have not been fully described, and scarcely require distinct notice. They are all soluble, even those with earthy bases, and in general crystallizable. The metallic benzoates are equally uninteresting. The acid itself, though retained in the materia medica, has no medicinal virtue, and is employed merely in some officinal preparations in which it has long been an ingredient.

SECT. XIX.—*Of Acetic Acid.*

THIS, like several of the other vegetable acids, is a native production, and is also capable of being artificially formed. It exists in the sap of vegetables, combined with potash and lime, and is discovered by evaporating the sap, and adding to the solid matter sulphuric acid; the vapours of acetic acid are then perceived by their smell. It is more peculiarly, however, the produce of fermentation; and the production of it even characterizes one stage of that process. It is under it, therefore, that its chemical history is best placed.

SECT. XX.—*Of Prussic Acid.*

PRUSSIC ACID is usually obtained in the decomposition of certain animal substances by heat, from new combinations of the elements of animal matter. But it has lately been discovered, that it exists as a product of the vegetable system. It had always been observed, that this acid has the peculiar fragrant smell of peach-blossoms; and it had also been observed, that the same smell is perceptible in the distilled waters from the leaves of the cherry-laurel, the seeds of the bitter almond, and some similar vegetables, all of which are more or less narcotic. Bohn at length found, that when potash is added to the water distilled from the bitter almond, it acquires the property of forming a blue precipitate with solutions of iron,—the sure indication of the presence of prussic acid. This has been confirmed by Vauquelin, Bucholz, and other chemists; and similar results have been obtained from the distilled waters of the peach-blossom and the cherry-laurel, even prussiate of potash being obtained crystallized, by distilling them from potash, and the acid being also abstracted from the oil of these plants. Prussic acid, therefore, may be classed with the vegetable acids; but as it is more peculiarly formed from animal matter, and is more analogous in composition to animal substances, its history will be afterwards delivered.

SECT. XXI.—*Of Moroxylic Acid.*

THIS name has been given by Klaproth to an acid which he extracted from a saline efflorescence, found on the trunk of the white mulberry (morus alba.) He regards it as a peculiar acid, though farther investigation may perhaps connect it with one or other of the acids already known. In its properties it approaches nearest to the succinic acid.

The saline exudation consists of this acid in combination with lime, and mixed with a portion of extractive matter. The acid was obtained by two processes. In the first, to a solution of the salt a solution of acetate of lead was added; and the precipitate formed, consisting of the acid united with the oxide of lead, was decomposed by sulphuric acid. In the second, the salt itself was decomposed by sulphuric acid, the sulphate of lime being separated.

This acid is similar to succinic acid in its taste. It remains dry on exposure to the air, and is soluble both in water and in alkohol. When heated in a retort, a small quantity of acid liquor is first obtained; a concrete salt next rises, which condenses in the form of prismatic crystals, colourless and transparent; a little charcoal remains in the retort, the sublimed matter is the acid, free from the extractive matter which adheres to it when it is prepared in the humid way. In its pure state, it does not precipitate the metallic solutions; but the native salt from which it is extracted, throws down precipitates from nitrate of silver and acetate of lead.

SECT. XXII.—*Of Wood, Cork, and Suberic Acid.*

THE wood of vegetables is the base to which the other principles are attached, forming the structure of the plant, and the greater part of the substance of which it is formed. Its properties are sufficiently characteristic to give it a claim to be regarded as a distinct principle.

Wood is fibrous in its texture. It is inodorous, insipid, and generally free from colour, though it is also frequently possessed of colour, taste, and smell, from the presence of extractive matter, mucilage, resin, or essential oil, and it is only when these have been extracted by the action of water and alkohol, that the wood can, as a chemical principle, be regarded as pure. In this state it is insoluble in water; even when the water is boiled on it, it is not dissolved. It is equally insoluble in alkohol: and hence it forms the residuum, when any of the solid parts of plants have been acted on by these fluids. From the action of the air, if it is dry, it does not appear to suffer any change; but when humid, it is gradually decomposed, and passes through various intermediate states to that of a black mould, consisting principally of carbon. The oxygen of the atmospheric air is, during this change, consumed, and carbonic acid formed with a portion of water, and the latter, being derived from the combination of the oxygen, leaves carbon predominant. When the air is entirely excluded, wood decomposes with extreme slowness, even though humid, as, for example, when it is buried in the earth. When the action of water is favoured by a high temperature, it appears to produce, however, a decomposition of wood, whence, after the first action of the air, a portion of extractive matter is formed, which the water dissolves; and hence, as Saussure found, it is impossible to reduce wood by repeated decoctions in water to that state in which it shall not yield by a new decoction with the aid of the action of the atmosphere, a portion of extract.

The alkalis act on wood, and stain it of a dark colour; with the assistance of heat, they soften, and partly dissolve and decompose it.

The stronger acids also act on it. Sulphuric acid chars it, rendering it speedily black and soft. Nitric acid gives it a yellow tinge; and when acted on in large quantity, disengages nitrogen gas, and converts it into oxalic acid, with small quantities of malic and acetic acids.

Wood suffers decomposition from heat, a large quantity of an acid liquor distils over, with a portion of empyreumatic oil; carburetted hydrogen, and carbonic acid gases are disengaged, and a portion of ammonia is produced, which is neutralized by the acid. A charcoal remains, which retains the figure, and even the texture of the wood. The acid procured in this process, was formerly regarded as a peculiar one, and named Pyro-ligneous Acid; but the researches of Fourcroy and Vauquelin have shewn, that it is diluted acetic acid, with an impregnation of empyreumatic oil.

When the air is admitted, and the heat raised to ignition, wood burns. Its combustion at first gives much light, from the extrication of the hydrogen in combination with a part of its carbon; but as this is dissipated, the light is diminished, and there is at length only the red glow of the charcoal. The products of the combustion are principally carbonic acid and water; and if nitrogen be a constituent principle of wood, as its analysis by heat appears to prove, ammonia will probably also be evolved. An ammoniacal salt is accordingly always found in the soot of fuel.

Wood, from the products of its combustion, or of its decomposition by heat, appears to consist of carbon, hydrogen, and oxygen. It is evidently, of all the vegetable principles, that which contains the largest proportion of carbon; since, independent of the quantity of this principle disengaged in its analysis, in the state of carbonic acid and other elastic products, the residual charcoal amounts to one fourth or fifth of the weight of the original wood. This charcoal always contains a portion of saline matter, which it affords by incineration, principally carbonates, sulphates, and muriates of potash and lime, and also earthy and metallic matter, principally silex, iron, and manganese. Some of these may be essential to the composition, but, from the researches of Saussure, it appears that they are often derived from the soil.

Cork, the external bark of the Quercus Suber, is analogous to wood. It is light, soft, spongy, and elastic; is inflammable; affords a little ammonia by distillation, and is acted on by chemical agents in nearly the same manner. The principal peculiarity with regard to it, and in which it differs from wood, is that, when acted on by nitric acid, it affords a peculiar acid, hence named the Suberic.

To obtain this acid, diluted nitric acid is distilled from cork with a gentle heat, the distillation being continued, until the production of red vapours ceases; the whole, while warm, is poured into a porcelain bason, placed on a sand-bath, and a moderate heat is applied, stirring the matter constantly until it ceases to exhale white irritating vapours. A concrete soft substance is thus obtained, of a yellow colour, which is to be put into a matrass, and diluted with twice its weight of distilled water; it is heated so as to liquify it, and the solution is filtered from the part that is not dissolved by the water. The solution is coloured, but the colour is removed, either by saturating it with an alkali, and precipitating it by an acid, or by boiling it with charcoal.

Suberic acid is not crystallizable, but may be obtained by evaporation in pellicles, or by precipitation in powder. Its taste is slightly bitter and acid; it reddens the vegetable colours. Exposed to heat, it is volatilized, and forms crystalline flakes on the sides of the vessel. Heated by the blowpipe, it liquifies, then becomes pulverulent, and is sublimed. It becomes brown from exposure to light.

It is sparingly soluble in cold water; boiling water dissolves half its weight of it. Alkohol developes in it an aromatic odour.

Suberic acid unites with the alkalis and earths. Its salts are named Suberates. Those with alkaline bases are soluble, and have a bitter saline taste; those with earthy bases are in general of sparing solubility, but have also the same taste. The mineral acids in general precipitate the suberic acid from their solutions; and they are decomposed by solutions of almost all the metallic salts.

A character peculiar to this acid is, that when a few drops of it are added to a solution of indigo in sulphuric acid, it causes the blue colour to pass to a green. Lagrange has pointed out other characters by which it is distinguished from the known vegetable acids; from the citric, by not crystallizing; from the gallic, by not precipitating iron black; from the malic, by being obtained in a concrete form; from the tartaric, by its volatility; from the oxalic, by not precipitating the solution of sulphate of copper, and by yielding to it lime. From these, and the phenomena presented in its combinations, he considers it as proved to be different from all the other acids, a conclusion which may be just, though it is to be remarked, that it does not appear to have ever been obtained pure, a portion of extractive matter adhering to it, which may give rise to some of its properties.

THE Ligneous Fibre is probably the basis of other vegetable productions, as of the fibres of flax, cotton, and other vegetables which are dressed and wove in cloth. They agree with it in their natural production and texture, and in chemical qualities; particularly in inflammability, insolubility in water or alkohol, and in the changes they suffer from the alkalis, the mineral acids, and other re-agents. Any differences they do present, are probably to be ascribed to their state of aggregation, or to slight modifications of composition.

SECT. XXII.—*Of Colouring Matter, Aroma, Acrid Principle, Bitter Principle, Narcotic Principle.*

FROM the imperfections of chemical analysis, it has not been always found practicable to refer some important properties of certain vegetable products to any known proximate principles; and in cases of this kind the existence of peculiar principles, in which these properties reside, has been supposed,—a supposition apparently confirmed by the fact, that with the property itself certain peculiar chemical relations are connected. Thus, in vegetable substances possessed of deep or brilliant colours, the colour is frequently found to be capable of being abstracted from the vegetable matter by chemical agents, and transferred, apparently by the exertion of chemical affinities, to others; thus, indicating its existence in a principle, which, however, from its general properties, cannot be identified with any of the established principles. The same conclusion, it has been supposed, may be drawn with regard to the odour of plants. And there are even facts, whence it has been inferred, that bitterness, an acrid quality, and the narcotic quality, sometimes reside in a principle peculiar to each.

The justness of the reasoning on which this kind of classification has been established, may well be called in question; for all these properties, even in vegetables, reside in principles of different kinds. The colour, for example, does not belong to a principle of uniform properties; and there is not more propriety in admitting the existence of a principle of colour or of smell than a principle of taste, all such qualities arising from modifications in the composition of any of the varieties of vegetable matter. Still, however, the chemical facts which have been referred to the operation of such principles, and which the present state of the science does not admit of being classed with more precision, require to be stated; they may therefore be so far generalized, keeping in view only the improbability of the assumption that such principles exist. As thus connected merely by an imperfect hypothesis, I place the consideration of them under this section, concluding the history of the individual vegetable products.

1. Colouring Matter.—Many of the vegetable substances used from the richness of their colours in the processes of dyeing, have chemical relations, whence there is some reason to infer the existence of a principle in which their colour resides. This colouring matter, too, appears analogous in several of its properties to the proximate principle denominated Extract. Still it is not uniform in its chemical characters; farther investigation must determine how far it is connected in its different varieties with any of the other proximate principles; and at present the general facts belonging to the subject only can be stated. They are interesting from their relation to the chemical arts of dyeing and pigment-making.

The colouring matter of vegetables is seldom found insulated. It is either mixed with other principles, or diffused through the leaves, bark, or wood, and is extracted by the operation of certain solvents.

Water, cold or warm, often dissolves it; sometimes it is not soluble in water, but in alkohol; frequently its extraction is facilitated by the action of acids or of alkalis; facts which prove that the colour is in reality attached to principles which are far from being alike.

When dissolved, the colouring matter may often be abstracted from the solvent by substances which appear to exert an attraction to it. Argil and metallic oxides, in particular, exert actions of this kind. The former, if diffused or boiled in a coloured vegetable infusion, frequently attracts the principle in which the colour resides so completely, that the liquor remains colourless. Or if alum be dissolved in a coloured infusion, and it be decomposed by the addition of an alkali, the argil in the moment of its precipitation attracts the colouring matter with a similar effect, and also forms a coloured precipitate. In like manner, if a coloured infusion be boiled with a metallic oxide, or a metallic salt dissolved in the infusion is decomposed by an alkali, it often happens that the colouring matter is attracted by the oxide. It is apparently from similar affinities to the colouring matter that it is often attracted by linen, cotton, silk, or wool, from its solutions; and even where the affinities of these are not sufficiently powerful, they may be rendered capable of attracting it, or the combination may be rendered more permanent, by their being impregnated with another substance, which has towards it a still stronger attraction. Lastly, the shade, and even frequently the tint of colour, are altered by chemical agents, The alkalis, acids, and various neutral and metallic salts, exert operations of this kind.

On these principles rest in a great measure the art of dyeing, the processes of which are arrangements founded on the affinities of colouring matter, in consequence of which colours are extracted, modified, transferred to the cloth, and rendered more permanent. For this view of the subject we are principally indebted to Bergman. In immersing pieces of wool and of silk, in a solution of indigo in sulphuric acid, largely diluted with water, he observed, that the wool was speedily dyed, and that if the proper proportions were observed, the solution in which it was immersed was deprived of colour. The silk was dyed more weakly; it only lessened the colour of the solution, but did not abstract it entirely. These phenomena he ascribed to the different forces of attraction exerted by these substances towards the colouring matter. In consequence of such an attraction, the sulphuric acid had dissolved the indigo; the silk exerted, however, to the particles of the indigo, a stronger attraction than the diluted acid did in which they were dissolved: it therefore abstracted them from the fluid. And the wool did this still more completely, as having to these particles a still stronger attraction.

Even where the substance to be dyed has little or no attraction to the matter on which the colour depends, so as either not to be capable of abstracting it from its solvent, or of retaining it with such force, as to form a permanent dye, the colour may be communicated and rendered permanent by the intermedium of a substance which, having an attraction on the one hand to the colouring matter, and on the other to the cloth or thread, shall serve to unite them. Such substances are named Mordants, and their use is essential in the processes of dyeing. The principal mordants are alum, acetate of argil, muriate of tin, sulphates of copper and zinc, acetate of copper, oxide of arsenic, tannin, and certain animal substances. Of those of the saline kind, it is not so much the entire salt, as its earthy or metallic base, that serves to fix the colouring matter; and in the course of the process it is often disunited from its acid. Hence the extensive application of alum, and of the solutions of tin, as mordants, from the powerful affinities of argil and oxide of tin to colouring matter. Sometimes mordants are employed rather to heighten the colour, or give it more brilliancy, or communicate a particular shade. With these different views, they are susceptible of a great variety of applications, with regard to the various dyes and the different cloths; and the proper management of them constitutes the principal part of the art of dyeing.

The art of cloth-printing, or calico-printing, in other words, of dyeing in certain colours particular spots of the cloth, or figures impressed on it, while the ground shall be of a different colour or entirely white, depends on the same principles. A mordant is applied by a stamp to the part on which the figures are to be impressed; it thus receives a permanent dye, while the colour of the rest of the cloth is easily discharged, thus leaving a coloured design on a white ground. The mordants principally used in this process, are the acetate of argil and acetate of iron, these, with logwood, quercitron, and other colouring substances, giving different colours.

The formation of the vegetable pigments, or what are named Lakes, affords another exemplification of the affinities of colouring matter. The colour is extracted by its proper solvent, generally by water; and there is added to the solution some substance capable of attracting and combining with the colouring matter, so as to form a precipitate. Thus, if alum be dissolved in an infusion of brazil wood, and an alkaline solution be added, the argillaceous earth is precipitated, and carries with it the colouring matter, forming therefore a lake. Similar lakes are formed from other coloured vegetables; and the most beautiful of them, carmine, is prepared by a similar process from cochineal, a colouring substance of animal origin.

The vegetable substances used in dyeing are extremely numerous. The colouring matter of the greater number of them, such as all the woods and barks, logwood, brazil wood, weld, quercitron, &c. appears to approach in its characters to extract, and admits, therefore, of few observations as to their chemical history, farther than what have been already stated. Indigo is a substance more peculiar, and with regard to which there are some singular facts. It is in some measure an artificial preparation. The plant which affords it, being cut when ripe, is put into troughs with water, and pressed down. A species of fermentation is soon excited, and a quantity of aërial fluid is disengaged, partly inflammable. The water becomes turbid, and when the process has been sufficiently advanced, it is drawn off into another trough, where it is kept agitated, to promote the separation of the colouring particles. Towards the end of this stage of the operation, a portion of lime-water is added, which still farther favours this separation. The liquor is withdrawn into another vessel, in which the deposition is allowed to go on; and the indigo, which forms its solid matter, is obtained by gentle pressure in the state of a paste, which is dried by exposure to the air, excluding the solar rays. The rationale of the process by which it is prepared is not well understood. The plant, by expression or infusion, affords only a green colouring matter previous to the fermentation; and we have no precise facts from which it can be determined how this fermentation is so easily excited, what are the changes it occasions, or how these are connected with the production of the colouring matter.

Indigo is of a rich blue colour; it is light and friable, has a smooth fracture, is tasteless, and has scarcely any smell. With its pure colouring matter it contains other principles, particularly a portion of gummy and of resinous matter, earth, and oxide of iron. It yields its mucilaginous part to water, but the colouring matter is not dissolved. It is equally insoluble in alkohol, or in ether, a small portion of the resin only being dissolved.

The action of acids on indigo is more energetic and important. Concentrated sulphuric acid dissolves it even in the cold; the solution appears black, from the deepness of its colour, and even when largely diluted with water, retains a deep blue colour. The colour is changed to a green, by the action of a number of substances upon it; as by sulphurous acid, vinegar, ammonia, alkaline sulphurets, sulphate of iron; and by some of these the colour is entirely destroyed. The alkaline carbonates throw down from the solution a blue powder, which Bergman named Precipitated Indigo.

The action of nitric acid on indigo, when the acid is concentrated, is even so violent as to inflame it; and when diluted, it still acts on it forcibly, and decomposes it; a substance is formed, which, freed from nitric acid by washing, forms a brown-coloured mass, of a strong bitter taste, requiring a large quantity of water for its solution, and more soluble in alkohol. This is the substance which has received the name of Bitter Principle, and which, as a product of the action of nitric acid on different varieties of animal matter, is afterwards to be noticed. A little oxalic acid is also formed, and a portion of tannin.

Muriatic acid does not act on the colouring matter of indigo, but dissolves the oxide of iron and the earthy matter. The greater number of the other acids act on it in the same manner. Oxy-muriatic acid destroys its blue colour.

The fixed alkalis extract a portion of matter from indigo, but not that in which its colour resides. They dissolve, however, precipitated indigo, but the blue colour gradually changes to a green, and is at length destroyed.

Indigo, when exposed to heat, swells, emits vapours, and burns slowly with a white flame. The residuum consists of earthy matter and oxide of iron. The colouring matter, by destructive distillation, affords carbonic acid, carbonate of ammonia dissolved in water, empyreumatic oil, and charcoal. It consists, therefore, of hydrogen, oxygen, nitrogen, and carbon, the proportion of carbon being unusually large.

The chemical properties of this substance are peculiar, and are evidently such as prevent it from being considered as a variety of any other known principle. The application of it to the art of dyeing presents, too, some singular phenomena; for although it is not soluble in alkaline solutions or in lime, yet, by the intervention of other substances, this solution is effected, so as to form a dye-liquor. These, which are in general metallic preparations, as sulphate of iron, or sulphuret of arsenic, appear to operate by abstracting oxygen, by which the indigo is rendered soluble. It at the same time becomes green, but the cloth dyed in the liquor becomes blue on exposure to the air, probably by regaining oxygen.

WOAD is a substance produced by a process similar to that followed in extracting indigo from a different plant. It gives a blue colour, which is permanent, but has not the beauty of that from indigo. If this plant, however, be subjected to precisely the same process as that followed in preparing indigo, it affords a blue colouring matter the same; and there can be little doubt, therefore, that the colouring matter of woad is indigo less perfectly prepared.

ANNOTA is prepared, by a process somewhat similar, from the seeds of the Bixa Orellana. It is of an orange colour, is not perfectly soluble in water, but the addition of an alkali renders it more soluble, and gives it a bright orange-yellow colour. Acids form with this liquor an orange-coloured precipitate. It is more soluble in alkohol than in water.

From different species of lichen, is prepared the colouring matter known under the names of Archil and Litmus, so useful to chemists, as the most delicate test of acidity. The plant is reduced to powder; a quantity of alkali is added to it, and it is kept moist; it ferments, and gradually acquires a blue or violet colour; it is then dried. Litmus, or Turnsole, is a similar substance, apparently in a more pure state. The colouring matter is extracted by water; if the solution be kept secluded from the air, the colour entirely disappears; but it is quickly renewed when the air is admitted. It is also soluble in alkohol, and exhibits the same phenomenon. It is instantly reddened by the weakest acid liquor; and hence the watery infusion of it, or paper stained with this, affords a very delicate test.

Aroma.—The odour of plants generally resides in their essential oil; but it has been observed, that there are plants smelling strongly, as the violet or the jessamine, from which either no oil can be procured, or, if obtained in small proportion, it has not that strength of odour which might be looked for, did this quality, as possessed by the plant, depend on it. These plants, too, lose their odour by exposure to a very moderate heat, not sufficient, it has been supposed, to volatilize the essential oil. And hence it has been concluded, that there exists an Aroma or Principle, in which their odour resides; that this is capable of being combined with their other principles, and that it is even on its presence that the essential oils have usually the odour of the plant.

This hypothesis rests on very feeble grounds. The odour of plants may reside in any of their principles, arising, like other sensible qualities, from modifications of their composition; it does, in different vegetables, exist in principles of different kinds; there is no direct proof of the existence of any subtle principle of this nature; and all the facts supposed to be favourable to the hypothesis admit of explanation, on the supposition that the odour resides in the essential oil; that this is sufficiently volatile to be dissipated at a very moderate temperature; that it may be diffused in atmospheric air, or dissolved by it; and that, suffering chemical changes from long exposure to the atmosphere, it is deprived of much of its smell by age.

Acrid Principle.—There are a number of plants which, in their recent state, are extremely acrid to the taste, and display this acrimony in the irritation and inflammation which they occasion when applied to the skin: yet they lose this peculiar acrimony on being dried, while their more active powers frequently remain. From some of these plants, too, this acrimony is communicated to water or alkohol by distillation from them, though no other property, not even odour, is thus conveyed. It has been concluded from these facts, that there exists a peculiar volatile principle in these plants different from an essential oil, in which their acrimony resides. If its existence shall be considered as probable, however, it has never been obtained in such a state as to be submitted to chemical examination, and all that relates to it is therefore uncertain and obscure.

NARCOTIC PRINCIPLE.—The narcotic power belonging to some vegetables, it has been found, is impaired or lost by decoction in water, though, when the operation is performed so as to condense the water volatilized, it is not found to be impregnated with any essential oil; nor are essential oils usually possessed of such active powers. In some cases, the distilled water, as for example that from the leaves of the cherry-laurel, has a narcotic quality; in other cases it has none. From such facts, the existence of a narcotic principle has been inferred.

The loss of narcotic power by decoction, in those cases where it is not communicated to the water distilled from the vegetable which possesses it, is probably to be ascribed, not to the dissipation of any volatile principle, but to changes of composition. Where it is communicated to water, it appears now to be established, that it is the prussic acid. This acid has been discovered, as already remarked, in the cherry-laurel, the bitter almond, and other narcotic plants. It has also been found, that, in its pure state, it is narcotic; and there is therefore every probability in the conclusion, that that quality in these vegetables depends on its presence. But there is no reason farther to infer that it is the narcotic principle; for there is none to presume that it exists in other narcotics, and it is itself inferior in narcotic power to some vegetable products. A substance has been said to be extracted from opium by the alternate action of water and alkohol, which has even been obtained in a crystalline form; and this matter having been found to be more powerfully narcotic than opium, it has been regarded as the principle on which the powers of that drug depend. The results, however, still rest on authority rather uncertain; if they were admitted, it does not appear that this substance is very powerfully narcotic, and there is no proof of its being contained in any other narcotic vegetable.

Bitter Principle.—It has been supposed, that a principle exists in some of the vegetable bitters, in which their bitterness resides. The properties, however, assigned to it, particularly its equal solubility in water and in alkohol, and its precipitation by certain re-agents, appear to prove, that what has been considered as such is a variety of extract. And were its existence established, the name that has been given to it, implying that it is the principle of bitterness, can with no propriety be assigned to it, since so many substances possess this quality, in which it cannot be supposed to exist. A product of the action of nitric acid on certain vegetable and animal substances has, from its intense bitterness, been distinguished by the name of Bitter Principle. There is no reason to believe, however, that it is ever naturally formed; and it cannot therefore be regarded as a principle of vegetables. As a product of decomposition, it is afterwards to be noticed.

CHAP. III.

OF THE SPONTANEOUS CHEMICAL CHANGES AND DECOMPOSITION OF VEGETABLE SUBSTANCES.

BESIDES the peculiar chemical changes to which the individual vegetable products are liable, there is a series of changes of which they are more or less susceptible, arising from the spontaneous re-action of their elements at natural temperatures, which chemists have been accustomed to class together, as forming the general process they have named Fermentation. And of this process three stages have been distinguished, marked as well by the phenomena which attend them, as by the peculiar products they form;—the Vinous Fermentation, of which vinous spirit is the product,—the Acetous, from which acetous acid or vinegar is formed,—and the Putrefactive, in which the elements are disengaged in new combinations in the elastic form. These do not always succeed each other, as it is not every substance that is capable of passing through the changes which constitute each: but when they do, the vinous always precedes the acetous, and this again is terminated by the putrefactive.

SECT. I.—*Of the Vinous Fermentation.*

SACCHARINE matter is the principle more peculiarly liable to the vinous fermentation. Sweet vegetable juices pass into it readily, as do those substances which are capable of becoming sweet, such as the fecula of grain. When the fermentation commences, the liquor, if transparent, soon becomes turbid; a kind of intestine agitation of it takes place; a quantity of aerial matter is formed, and disengaged; the temperature rises, and this continues until the fermentation is completed, which requires a longer or shorter time, according to the quality of the fermenting liquor; it then becomes transparent, depositing a sediment, and its qualities are found to be wholly changed; it has lost its bland and sweet taste, and acquired a greater or less degree of pungency; and it is capable of acting more powerfully on the living system, producing an exhilirating or intoxicating effect. The elastic fluid disengaged during the process, is carbonic acid gas, accompanied sometimes, in the fermentation of fecula, with a portion of hydrogen gas. No peculiar agency is exerted by the atmospheric air, nor is its presence even necessary to the series of changes.

The process of vinous fermentation is, to a certain extent, dependent on external circumstances. Thus a due degree of temperature is required; it proceeds with most uniformity at a temperature from 50 to 55. At 32° it is checked, and at 60, or higher, it is too rapid, and is liable to pass, before it is completed, into the acetous stage. A certain extent of dilution with water is also necessary. If the impregnation of saccharine matter is too great, the process is retarded; if, on the other hand, the liquor is too much diluted, it is liable to become sour as the fermentation proceeds. Lastly, the presence of a ferment is in general required. A solution of pure sugar scarcely passes into a state of fermentation, or does so very imperfectly, and rather forms a sour, than a vinous liquor. The substance by which fermentation is excited, is the scum collected on the surface of a liquor already in fermentation, or the sediment which is deposited, Yeast, as it is named. This added to any liquor capable of fermenting, causes the fermentation very soon to commence, and to proceed rapidly.

The nature of the matter in yeast, by which fermentation is excited, has been the subject of research, but is not perhaps altogether ascertained. Rouelle remarked, that it affords ammonia by destructive distillation; and Lavoisier inferred, that it contains nitrogen. From the experiments of Fabroni, Thenard, and Seguin, it appears to be analogous to gluten or albumen, and to be originally derived from those sweet vegetable juices which are capable of fermenting without any addition, as the juice of the grape. According to Fabroni, it is contained in this fruit, and also in the nutritive grains; it is deposited from the juice, or from the infusion of the grains, and if added to another sweet liquor, causes it to ferment; the gluten of wheat, with the addition of a little tartar by which its solubility in water is promoted, has a similar effect. Thenard obtained from the juice of the gooseberry, by filtration, a substance slightly glutinous, which, added to a solution of sugar, caused it to ferment; and the same substance he found to be deposited from the juices of the grape, apple, and other fruits, during their fermentation. After drying, it is still capable, when added to a sweet liquor, of exciting fermentation; it is scarcely soluble in water, is decomposed by nitric acid, nitrogen gas being disengaged; it is liable to putrefaction, and affords, by destructive distillation, the same products as animal matter. This principle, on the whole, seems to be analogous to vegetable gluten.

Sugar, it has frequently been supposed, is the only vegetable principle susceptible of the vinous fermentation; the fecula of the nutritive grains passing into it, it was imagined, only after having been subjected to the process of malting, in which there is the transition into saccharine matter. It is now known, from the practice of the spirit-distillers of this country, that this preliminary process of malting is not indispensible; they always add a portion of unmalted to malted grain, the former is often even in larger quantity than the other; and the infusions of this pass into the vinous fermentation, on the addition of yeast. Fourcroy and Vauquelin have shewn by experiment, that unmalted grain alone can be made to ferment, and afford a liquor, which, by distillation, gives alkohol. As fecula consists of the same principles as sugar, differing only in the proportions, it is not difficult to conceive, that by the series of changes which fermentation establishes, it may afford the same product.

The theory of fermentation is still imperfectly understood. Its ultimate result is, the formation of a peculiar principle, volatile and inflammable, which can be obtained, by distillation, from the fermented liquor; diluted, and with some degree of intermixture, it forms the common spirituous liquors; and in its pure form, ALKOHOL. But there is still much uncertainty with regard to the changes by which saccharine matter, or fecula, is converted into this product.

Sugar being a compound of carbon, hydrogen, and oxygen, carbonic acid gas being disengaged during fermentation, and no oxygen being absorbed from the air, Lavoisier supposed that part of the oxygen and carbon of the sugar combine, and form this carbonic acid, and that its hydrogen, with the remaining carbon and oxygen, form the alkohol. But to this simple theory the objection is obvious, that the agency of the ferment or yeast, so essential to the process, is not explained. This has since formed a subject of investigation. Fabroni has supposed, that it operates by its carbon attracting part of the oxygen of the sugar, forming the carbonic acid, while its hydrogen and nitrogen combine with the remaining elements of the sugar, and form alkohol. Thenard has given a similar view, the yeast operating, as he supposes, by subverting the equilibrium of affinities established among the elements of the sugar, by the attraction which its carbon exerts to oxygen; it thus forms part of the carbonic acid which is disengaged, and gives rise to the new combinations, whence the remaining carbonic acid and alkohol are produced. A very different hypothesis is advanced by Seguin, founded on the supposition, that a portion of water is decomposed in fermentation; its oxygen, he infers, combines with the carbon of the ferment, forming carbonic acid, while the hydrogen combines with the saccharine matter, and converts it into alkohol,—an hypothesis to which there are the obvious objections, that the product of alkohol ought to exceed the quantity of sugar, and that the small quantity of ferment cannot afford the carbon necessary to form the large quantity of carbonic acid disengaged. The subject still requires investigation, particularly with regard to the agency of the ferment: but the ultimate result of the process appears to be, as Lavoisier supposed, the abstraction of much of the carbon and oxygen of the saccharine matter, and hence hydrogen predominates in the composition of alkohol.

From the saccharine juices of fruits wines are formed by fermentation, and by the same process liquors somewhat analogous are formed from the nutritive grains. These fermented liquors differ in their strength and flavour. The wines from the juice of the grape are superior to the others; those from other fruits are weaker, and are acescent, or liable to become so; and the fermented liquors from the nutritive grains, retain some mucilaginous and extractive matter: all these afford spirituous liquors by distillation, the wine of the grape yielding the purest and strongest product. The alkohol which forms the active principle of these varieties of ardent spirit, was usually supposed to pre-exist in the wine, or fermented liquor, and, from its volatility, to be separated merely by the distillation. Fabroni, finding that wine could not be produced by adding the product to the residual liquor of the distillation, inferred that the alkohol is actually formed during the distillation from new combinations of the principles of the fermented liquor. But it is easy to suppose, that the changes of composition established by the high temperature, towards the end of distillation, may give rise to the circumstance from which this conclusion has been drawn; and the fact, that wine has the power of acting on the living system, peculiar to alkohol, and that with a force proportional to the quantity of this product which it yields by distillation, affords reason to conclude that it contains the alkohol fully formed, or at least in a state very analogous to that in which it affords it.

ALKOHOL is procured from spirituous liquors by repeated distillation; being volatile, it is thus freed from the water with which it is diluted. The process is usually facilitated, however, by certain additions. After the spirituous liquor has been once distilled, by which it is freed, not only from a considerable portion of water which remains in the still, but also from the oily or extractive matter, which gives it peculiar flavour, there is added to it a twelfth of its weight of the pearl-ash of commerce, previously exposed to a red heat. This attracts a considerable portion of water, which forms a dense solution that subsides; the spirit above is poured off, and distilled with the heat of a water bath, a small quantity of alum being frequently added, the acid of which, exerting an attraction to the portion of potash which the spirit may hold dissolved, prevents it from being brought over by its affinity to the vapour, and thus gives to the spirit a more fragrant odour. The alkohol thus procured, has still water combined with it, and even to an extent which we have not the means of appreciating. It may be obtained, somewhat more concentrated, by repeated distillations, with a very gentle heat, from potash, or from muriate of lime.

Alkohol, as obtained by the usual process, is of the specific gravity of 0.835, in which state it is sufficiently adapted to many of the uses, depending on its chemical agency, to which it is applied. It has been brought, by concentration, to the specific gravity of 800, or 798, at the temperature of 60°: when of the usual specific gravity, 0.835, it contains above 10 of water, which may be abstracted in its higher rectification. The proportions of alkohol and water, at other degrees of specific gravity, have been determined by Gilpin, from a very extensive series of experiments.

Alkohol is colourless and transparent; its odour is fragrant, and its taste pungent; it acts powerfully on the animal system, producing exhiliration and intoxication. It retains its fluidity at the greatest degree of cold hitherto reached; it is highly expansible from heat, and volatile; it evaporates quickly under exposure to the air, and in close vessels boils at 165°. Its vapour transmitted through an ignited tube is decomposed, a large quantity of oxy-carburetted hydrogen gas with carbonic acid are formed, and charcoal is deposited.

Alkohol is highly inflammable. It kindles when the temperature is not much above 300°, when in contact with atmospheric air, and burns with a blue lambent flame, without any sensible smoke, and, when pure, without any residuum, affording merely water and carbonic acid gas; and the quantity of water that is condensed, exceeds even the weight of the alkohol consumed, so large a portion of oxygen being consumed in the combustion. Lavoisier from this experiment inferred, that 100 parts of alkohol consist of 28.5 of carbon, 7.8 of hydrogen, and 63.5 of water,—a conclusion liable to the objection, that there are no grounds for determining how much of the water obtained in the combustion exists in the alkohol in its entire state, and how much of it in the state of its elements, forming part of the combination itself. The experiment has been more lately repeated by T. Saussure, and from the results, he has given as the proportion of the elements of alkohol, carbon 48.82, hydrogen 15.82, oxygen 41.36; a conclusion still liable to the same objection, that we know not how much of this oxygen and hydrogen exist as the elements of alkohol, or how much of them exist in it in the state of water. From the results of its analysis, by passing it through an ignited tube, he farther found that a little nitrogen (3.5 parts in 100) is contained in it; and Thenard had before found, that the nitrogen of yeast disappears in fermentation, and had inferred, that although not easily detected in the alkohol, it enters into its composition.

Alkohol combines with water in every proportion; and although the properties are not much modified, the combination is marked by the specific gravity of the compound not being the mean of the specific gravities of the two fluids. It is always greater from the condensation that takes place. This condensation is accompanied with a diminution in the capacity for caloric, and hence, with a rise of temperature. Alkohol diluted with an equal weight of water, forms what is named Proof Spirit.

In consequence of its affinity to water, alkohol precipitates many of the neutral salts from their aqueous solutions. There are others which it does not precipitate, and which it even dissolves. It dissolves potash and soda in their pure form, and may be combined by distillation with ammonia. It also dissolves strontites and barytes in sparing quantities.

The acids combine with alkohol, and some of them decompose it; forming a particular order of compounds, the Ethers, as they are named, to be immediately considered.

Alkohol unites with sulphur, when the sulphur is presented to it in the state of vapour. The compound is a liquid of a reddish colour and fetid smell, resembling that of sulphuretted hydrogen: it becomes turbid on cooling, and sulphur is precipitated from it by the addition of water. Phosphorus is dissolved by alkohol: the solution is rendered turbid, and the phosphorus precipitated on the affusion of water; this being accompanied with a tremulous light. It does not dissolve carbon, nor does it combine with hydrogen.

Alkohol is the solvent of a number of the vegetable proximate principles, as sugar, resin, extract, camphor, essential oil, and several of the acids; hence it extracts the medicinal powers of many vegetables, and is employed in pharmacy, either in its pure form or diluted, to form tinctures. Solutions of resinous substances in it form varnishes.

THE action of the more powerful acids on alkohol is peculiar, and gives rise to an order of compounds, important from their chemical properties. These have been distinguished by the generic appellation of ETHERS. They differ in their qualities as produced by the different acids; but they also agree in the possession of certain general properties; they are highly volatile, odorous, pungent, and inflammable; miscible with water, and capable of combining with alkohol in every proportion. SULPHURIC ETHER, produced by the action of sulphuric acid on alkohol, is the one which has been longest known to chemists.

To prepare sulphuric ether, sulphuric acid is poured on an equal weight of alkohol in a retort; and after they are thoroughly mixed by a gradual agitation, heat is applied by the medium of a sand-bath, a large receiver being adapted to the retort, carefully luted, and kept cool by water. Distillation commences when the temperature is raised to 208°, and a colourless liquid condenses in the receiver. When the quantity of it amounts to about half the quantity of alkohol that had been employed, the heat is withdrawn. The residual liquid is of a dark brown or black colour. If a fresh portion of alkohol, not more than half of the first quantity, be added to it when it is cold, an additional portion of ether will be procured by a new distillation.

The ether condensed in the receiver by this process, is weak from the intermixture of water, and is usually also impure from the presence of a portion of sulphurous acid.

It is rectified by agitating it with sub-carbonate of potash, or muriate of lime, and distilling it a second time by a very gentle heat, putting into the retort from which it is distilled a small quantity of black oxide of manganese.

The theory of the formation of ether is still involved in some obscurity. Fourcroy and Vauquelin, from an experimental investigation of the process, inferred, that the sulphuric acid does not suffer decomposition; they supposed, therefore, that it acts merely by a resulting affinity, causing part of the oxygen and hydrogen of the alkohol to combine and form water; the balance of affinities among its elements being thus subverted, a portion of its carbonaceous matter is precipitated and diffused through the residual liquid, and the remaining elements entering into new combination from the ether.

The principal difficulty is to explain the agency of the acid, for the proof is not clear that no portion of it is decomposed; and the fact, that of the other acids, those form ethers most readily, which yield oxygen with greatest facility, rather favours the conclusion, that the communication of oxygen from the acid is necessary to establish the series of changes whence these products are formed. Still the series of changes themselves, which occur in the formation of sulphuric ether, appear to be sufficiently ascertained. There is evidently a formation of water, as the residual liquor is considerably diluted, and this appears to be derived principally from the combination of the oxygen and hydrogen of the alkohol; there is also a precipitation of a carbonaceous matter somewhat bituminous, which must equally be derived from the alkohol; its remaining elements, from the other; for no trace of the acid itself, or of its base, can be discovered in its composition. Hence sulphuric ether appears to differ from alkohol principally in the predominance of hydrogen; and to this its greater levity and volatility may be owing. It accordingly affords only water and carbonic acid in its combustion. From the quantities of these Cruickshank inferred, that the proportion of carbon to hydrogen is as 5 to 1, while in alkohol he supposed it to be as 8 or 9 to 1. Saussure has more lately stated the composition of sulphuric ether at 59 of carbon, 19 of oxygen, and 22 of hydrogen.

There are some other products disengaged in the process by which sulphuric ether is formed. Towards the end of the distillation, an oily-like fluid condenses, which the chemists have named Oil of Wine, and which some have supposed to be a compound of ether and sulphurous acid, while others have regarded it as of a composition analogous to ether, but containing a larger proportion of carbon. There is also disengaged at this stage of the process a considerable quantity of olefiant gas.

Sulphuric ether is a fluid extremely light; its specific gravity, when it is highly rectified, being so low as .716. It is colourless and transparent, has a pungent taste, and a penetrating, rather fragrant odour. It is highly volatile, evaporating rapidly at natural temperatures. It boils under the usual atmospheric pressure at 98°, and, *in vacuo*, boils at a temperature even below 32°. In its spontaneous evaporation, it absorbs a considerable quantity of caloric, so as to produce much cold. It congeals at —47°. It is inflammable, burns with a clear white flame, and without smoke, producing by its combustion water and carbonic acid. Its vapour, diffused in atmospheric air or oxygen gas, explodes when kindled.

Sulphuric ether is soluble in water, requiring about 10 parts for its solution. It dissolves in alkohol in every proportion. On the fixed alkalis or earths it exerts no action; with ammonia it combines by distillation. It dissolves sulphur and phosphorus in small proportions; and it resembles alkohol in the solvent operation it exerts on a number of the vegetable proximate principles.

Nitric Ether is formed by the action of nitric acid on alkohol; but, from the violence of this action, the process is difficult, and requires to be conducted with much caution. Various methods have been employed; that of Woolfe is generally preferred. It consists in adding to four parts of nitre in coarse powder in a retort, by successive small portions, a mixture of four parts of sulphuric acid, and rather more than three parts of alkohol, connecting the retort with a range of receivers, kept cool; nitric ether is formed and volatilized without the application of heat, and is condensed by passing the gaseous product through water, or through a solution of muriate of soda in the receivers. It floats above the liquor, and is purified from any free acid by agitation with lime, and a second distillation with a gentle heat.

The theory of the formation of nitric ether is still more obscure than that of sulphuric ether. It is sufficiently ascertained, however, by the experiments of Pelletier and Bayen, that the acid is decomposed; the alkohol likewise suffers decomposition, portions of oxalic and acetic acid with water are formed, but there is no deposition of carbonaceous matter, as there is in the formation of sulphuric ether. A considerable quantity of elastic fluid too is disengaged, which, according to the researches of Thenard, consists of nitrogen, carbonic acid, and nitrous oxide, holding a portion of nitric ether dissolved. This chemist has farther found, that after the free acid of the nitric ether at its first distillation is abstracted by lime, acidity is regained, when it is kept for some time either with or without the access of air; and this arises from the production of nitric and acetic acids, the elements of which must therefore exist in the composition of nitric ether. He hence concludes, that in the formation of this ether, a portion of the oxygen of the acid combines with much of the hydrogen, and part of the carbon of the alkohol forming water and carbonic acid; nitric oxide, nitrous oxide, and nitrogen, being disengaged; the elements of the remaining acid, he supposes, enter into combination with the remaining elements of the alkohol, and form ether. From the products of its analysis when it is decomposed by heat, he infers, that 100 parts of nitric ether are composed of 14.49 of nitrogen, 28.65 of carbon, 48.52 of oxygen, and 8.54 of hydrogen.

Nitric Ether has an odour strong, but less fragrant than that of sulphuric ether; it is light, volatile, and inflammable. When highly rectified, its levity is such that it floats on water; and its volatility is so great that it instantly evaporates when poured from a bottle, and it boils at 70° under the usual atmospheric pressure; it requires 50 parts of water for its solution, but combines with alkohol in every proportion.

When a smaller portion of nitric acid is added to alkohol than is sufficient to convert it entirely into ether, a product is obtained on distillation, having a fragrant odour, and somewhat acidulous, which has been named Spirit of Nitrous Ether, and has been regarded as nitric ether largely diluted with alkohol.

Muriatic Ether.—The action of muriatic acid in its common state on alkohol is so inconsiderable, that no product which can be regarded as a muriatic ether can be obtained from it. By the action of oxy-muriatic acid on alkohol, a liquid is obtained which has been regarded as etherial, but is rather of an oily nature. It appears, however, that when the acid is brought to act on the ether in a very concentrated state, a proper ether is formed; it is thus procured by distilling alkohol from concentrated muriate of tin, or by transmitting muriatic acid gas through alkohol, and afterwards distilling the impregnated liquor. Much of the success of the operation, Thenard finds, depends on the due regulation of the heat; and the process he has given consists in mingling equal parts by measure of alkohol and concentrated muriatic acid in a retort, exposing the retort, supported on a grate of iron, to the direct fire of a common furnace, there being connected with the retort a large bottle half-filled with water, with a tube of safety inserted, and to which a bent tube is adapted, terminating under an inverted phial filled with water: when the liquor is brought to boil the muriatic ether is disengaged in the gaseous form, and is collected in the phial.

In this state it is colourless, has a strong etherial smell, and a saccharine taste. At a temperature below 50°, it condenses into a liquid, which retains the same taste and odour, and is limpid. Its specific gravity is to that of water, at the temperature of 39°, as 874 to 1000. It evaporates rapidly, producing much cold. Cooled to —22°, it does not congeal.

This product has no sensible acidity; but, what is singular, when it is kindled, muriatic acid gas is immediately produced in large quantity; and this acid is also slowly evolved in it when it is kept for some time, as it is too by the action of sulphuric or nitric acid at a high temperature. From the products of its combustion, Thenard infers, that 100 parts contain 51.89 of carbon, 33.03 of oxygen, and 15.68 of hydrogen, with which are combined 41.72 of muriatic acid. Whether this acid exists in the combination fully formed, or only in the state of its elements, is not determined; the latter perhaps is more probable; as if it existed in the former state, the force of affinity by which it is retained can scarcely be supposed so energetic, but that it should be detected by the action of some of the re-agents which are tests of this acid.

Phosphoric Ether has been supposed to be formed by exposing to heat a mixture of alkohol, and concentrated liquid phosphoric acid. A portion of unchanged alkohol first passes over, but after this a liquid condenses, which has an etherial smell, somewhat fetid, and is slightly acidulous. On removing this by the action of lime or magnesia, and distilling it a second time, it assumes an odour more grateful, similar to sulphuric ether, has nearly the same specific gravity, is soluble in water in limited quantity, and is highly volatile and inflammable, burning without any smoke. The theory of its formation has not been determined.

Fluoric Ether has been said to be obtained in decomposing fluor spar by sulphuric acid mixed with alkohol, applying heat so as to produce distillation. On distilling the product a second time from potash, an etherial liquid is obtained, resembling sulphuric ether, and which may perhaps have been formed by the action of the sulphuric rather than of the fluoric acid.

Acetic Ether is obtained by distilling repeatedly alkohol from concentrated acetic acid; it gradually acquires an etherial odour, and after the third distillation and rectification by an acid, it forms a proper ether. A similar product is obtained by distilling the acid with alkohol and a portion of sulphuric acid. Thenard found, that in the first process, if the distillation be repeated ten or twelve times, the acetic acid is almost entirely decomposed, and the alkohol is all converted into ether. In this conversion he supposes that the elements of the acid combine merely with those of the alkohol. The odour of acetic ether is grateful; its taste is peculiar; its specific gravity is 866; it evaporates on exposure to the air, and boils at 123°. It is soluble in water, requiring scarcely eight parts for its solution; if to this solution an alkali is added, the odour and taste of the ether disappear, the alkali is saturated, and diluted alkohol is obtained by distillation. In burning, too, acetic acid is deposited, though the ether itself is free from all sensible acidity.

SECT. II.—*Of the Acetous Fermentation.*

WHEN the vinous fermentation is completed, if the liquor be kept under the same circumstances, with the admission of the atmospheric air, it begins to suffer another change. It loses its vinous fragrance and pungency, and becomes sour. When this is completed, an acid liquor is formed, Vinegar, the acid of which in its pure form is in chemical nomenclature denominated the Acetous, and the process by which it is formed, is named the Acetous Fermentation.

Every substance susceptible of the vinous, is susceptible also of the acetous fermentation, and this even without having previously become perfectly vinous; and there are substances incapable of the former, which undergo the latter, as vegetable infusions, or juices containing much mucilage with a little saccharine matter. Alkohol by itself is incapable of this change, and even to a certain extent counteracts it; hence strong vinous liquors do not so readily become sour as those that are weak.

The action of a ferment appears to be necessary to excite the acetous fermentation, and of this, vegetable gluten appears to be the base. The admission of the atmospheric air is indispensable; and its oxygen is absorbed, and appears to combine merely with carbon from the fermenting liquor, so as to form an equivalent portion of carbonic acid. Lastly, a due degree of temperature is required, the fermentation taking place slowly when the temperature is below 60°, and being accelerated when it is raised to 70°. When it is rapid, there is an intestine motion in the liquor, as there is in the vinous fermentation; it is turbid, its temperature rises, and there is a disengagement of elastic fluid. When it is complete, these appearances subside, and the liquor, depositing a considerable sediment, becomes clear.

There is still some obscurity with regard to the theory of the acetous fermentation. The strength of the acetous liquor which is formed being proportional to its previous vinous strength, and the vinous property being completely changed into acidity, while there is at the same time an absorption of oxygen, it was concluded that the change consists in the oxygenation of the alkohol of the vinous liquor, or as carbonic acid is at the same time disengaged, in the abstraction of carbon. But as alkohol alone does not suffer this change, and as the presence of mucilage, sugar, or other vegetable matter, is necessary, the theory is not complete; neither does it explain the operation of the ferment necessary to the process. Nitrogen appears to enter into the composition of vinegar, which the ferment probably affords.

Vinegar is of different degrees of purity and strength, according to the materials from which it is prepared; that from wine is purest and strongest; prepared from unrefined sugar, or from infusions of unmalted grain, it contains a portion of vegetable matter, which renders it liable to spontaneous decomposition. Along with the acid which is its base, vinegar always contains a portion of extractive matter, which gives it colour, and frequently also portions of malic and tartaric acids.

To obtain the pure acid, the easiest method is by distillation. It passes over with a portion of water, and is thus freed from the vegetable matter, and from the other acids, care being taken not to continue the distillation too long, nor to raise the heat too high, as the vinegar is liable to acquire an empyreumatic odour. Distilled vinegar, though pure, is however extremely weak, and hence other processes are employed to obtain it in a concentrated state.

Its concentration can be effected by freezing, the water congealing, and the acid remaining uncongealed; and by repeating the operation with greater degrees of cold, a very strong and pure acid can be obtained. Another method is to expel the acid from its saline compounds. Thus, if acetate of potash or of soda, rendered as dry as possible, be exposed to heat with concentrated sulphuric acid, or with super-sulphate of potash, the sulphuric acid combines with the base of the salt, and the acetic acid is disengaged. It is also obtained from applying heat to a mixture of acetate of lead, and dried sulphate of copper or iron. Or if verdegris, which is a compound of this acid with oxide of copper, be exposed to a heat gradually raised, the acid is volatilized, and is obtained in a very concentrated state.

It had been remarked, that the acid obtained by this last process is more volatile and pungent than that obtained by the other methods, and displays also some differences in its combinations. It was hence concluded, that it is different in composition, either containing a larger proportion of oxygen, which it receives from the metallic oxide in its preparation, or a smaller quantity of carbon, from a portion of this element being abstracted by the affinity exerted towards it by the metal. Hence the distinctive names were introduced, of Acetic and Acetous Acids, the former being applied to the acid procured from verdegris by heat, the latter to the acid existing in vinegar, and obtained from it in a state of concentration. The experiments of Adet, and more lately of Thenard, have shewn, however, that there are no grounds for this distinction; the acids obtained by these different processes, when brought to the same degree of purity and strength, having the same properties, and exerting the same chemical actions. There is, therefore, only one acid, and to this the name of Acetic is properly applied.

Acetic acid, highly concentrated, has an odour fragrant and penetrating; it is caustic, and, even when largely diluted, has a sour taste. It is capable of congealing, when exposed to intense cold. It is very volatile, its odour being quickly diffused when it is exposed to the atmosphere, and by a moderate heat it rises entirely in vapour: This vapour kindles on the approach of a burning body.

Acetic acid combines with the alkalis and earths, forming salts, which are named Acetates. They are in general soluble in water, and, from their affinity to it, are not easily crystallized. It combines, too, with the metallic oxides. The greater number of these combinations present nothing interesting, and it will be sufficient, therefore, to take notice only of the more important compounds.

ACETATE OF POTASH, formed by saturating distilled vinegar with potash, is obtained by evaporation of its solution, in the state of a white foliated mass; or if the evaporation is carried to a less extent, small prismatic crystals form slowly. This salt is extremely deliquescent, is soluble in little more than its weight of water, at 60°, and is also soluble in alkohol. ACETATE OF SODA is obtained by evaporation, in slender prismatic crystals, which are deliquescent, and are soluble in less than three parts of water, at 60°. ACETATE OF AMMONIA can scarcely be crystallized, as, when its solution is submitted to evaporation, it is partly volatilized, partly decomposed: by evaporation, however, with a very gentle heat, it may be obtained in acicular prisms.

The Earthy Acetates are all soluble, and, by evaporation, afford either a gelatinous viscid mass, or acicular crystals.

The Metallic Acetates are likewise, in general, soluble and crystallizable; those applied to any use, are the acetates of quicksilver, copper, and lead.

Acetate of Quicksilver is prepared by decomposing a solution of nitrate of quicksilver by adding a solution of acetate of potash; the acetic acid combines with the oxide of quicksilver, and when the solution has contained the metal at a low degree of oxidation, the acetate is copiously deposited in scales of a white colour, and brilliant silvery lustre. This salt has been used as a mild mercurial preparation.

Copper forms different combinations with acetic acid. The verdegris of commerce is a sub-acetate, prepared by stratifying copper plates with the husks of the grape, after the expression of the juice, and moistening them occasionally with weak vinegar. The copper is oxidated, and the oxide retains a portion of the acid combined with it; this forms a crust on the surface of the metal; it is scraped off and dried, and is of a light green colour. When it is dissolved in distilled vinegar, the excess of oxide is dissolved by the acid, and by evaporation of the solution, the neutral acetate is procured, crystallized in aggregated prisms, of a much deeper green colour; it is soluble in water and in alkohol, while the other is only partially dissolved. Both the acetate and sub-acetate are used as pigments, and also in the processes of dyeing, and in medicine, as escharotics.

Acetic acid forms, also, different combinations with lead. Cerusse, or white lead, which, triturated with oil, forms the common basis of paint, is prepared by exposing plates of lead to the vapours of vinegar; the lead is oxidated, and this oxide retaining probably a portion of acid combined with it, forms a crust on the surface. When this is digested in distilled vinegar, it is dissolved, and by evaporation of the solution, a mass is obtained, composed of a congeries of slender prisms, which, from its sweet taste, has been named Sugar of Lead; and which is used in medicine, and in several of the arts. This salt was regarded as acetate of lead, but it appears to be a super-acetate, or to contain always a slight excess of acid, which is necessary to its crystallization. Its crystals are acicular prisms, semi-transparent, of a white or yellowish colour, with a silky lustre; it is slightly efflorescent, is easily soluble in water, but appears to be partially decomposed, from the affinity of the water to the acid aided by its quantity. The neutral acetate is what has been known by the name of Goulard's Extract, prepared by boiling vinegar on litharge; it does not crystallize readily, and its crystals are plates; in its chemical relations, particularly to some of the vegetable and animal proximate principles, it differs considerably from the super-acetate.

Acetic acid acts on several of the vegetable products. It dissolves camphor, volatile oils, resins, and gum-resins, without materially modifying their properties.

The composition of acetic acid is not altogether determined. It obviously is composed, principally, of carbon, hydrogen, and oxygen, but the proportions are not ascertained; and from its affording ammonia, when decomposed by heat, it appears to contain nitrogen.

SECT. III.—*Of the Putrefactive Fermentation.*

THE process of putrefaction, in animal matter, consists in the formation, from new combinations of its elements, of products offensive in their odour, which escape in the aerial form. Few vegetable substances can be said to be liable to it, yet they undergo a species of decomposition somewhat analogous, in which a similar evolution of gaseous products takes place, so that only the saline and earthy matter of the vegetable substance at length remains. To this the name of the putrefactive fermentation has been given.

Those vegetable products which are either soluble in water, or imbibe it, are those more peculiarly liable to this series of changes; and the same circumstances favour it which favour the other kinds of spontaneous decomposition, particularly a moderately high temperature, and the access of the air. The elastic products disengaged, are compounds of carbon and hydrogen, and carbonic acid; the former, according to the researches of Saussure, appearing principally when the action of the atmospheric air is excluded by the substance being immersed under water; the latter when the air is admitted, the oxygen of the air combining with the carbon of the vegetable substance, to form the carbonic acid, and with its hydrogen forming water. There is no sensible production of ammonia or of gases containing sulphur and phosphorus, the evolution of which more particularly characterises animal putrefaction, a difference arising from the absence of these elements, and of nitrogen, in the composition of vegetable matter. Those few vegetable products, however, which contain them, present results in their ultimate decomposition similar to those of animal substances.

Carbon being in general the basis of vegetable matter, it frequently remains, forming a kind of inert residuum after the decomposition has proceeded to a certain extent, constituting what is named Vegetable Mould. This, when the air is excluded, is scarcely liable to any farther change, there being no other principles to re-act on it with sufficient force. If the air is admitted, however, its oxygen acts on its carbonaceous base, and forms carbonic acid; this abstraction of carbon allows part of the oxygen and hydrogen of the mould to combine and form water, and by these progressive changes, the decomposition is at length rendered complete, and nothing remains but the saline, earthy, and metallic substances, originally contained in the vegetable matter.

It appears, however, that from the operation of circumstances, probably principally the exclusion of the atmosphere, and the presence of pressure, the decomposition does not proceed beyond the accumulation of this carbonaceous residuum; the former circumstance removing the agency of oxygen, the latter preventing the formation of elastic products; and from the process conducted under these circumstances, and on vegetable matter originally composed principally of carbon, as wood, have probably principally originated the different varieties of bitumens and coal, the origin of which from the vegetable kingdom, it has already been stated, can be clearly traced.

BOOK IX.

OF ANIMAL COMPOUNDS.

THE chemical history of animal substances may, like that of the vegetable products, be considered under three divisions;—the first comprising what relates to their formation; the second including the details of their individual chemical qualities; and the third embracing the few general facts connected with the compositions to which they are liable from the re-action of the constituent principles, either at high or at low temperatures.

CHAP. I.

OF THE FORMATION OF ANIMAL SUBSTANCES.

ANIMAL substances are distinguished by nearly the same general chemical characters as vegetable products. They are formed of a few ultimate principles, the diversities in their properties arising chiefly from the proportions and the modes in which these are combined. From this peculiarity of constitution, they have the same susceptibility of decomposition as vegetable substances have, the balance of affinities among their elements being altered by slight variations of circumstances, and new combinations established. Hence, too, their analysis is always of the complicated kind, their principles not being disengaged insulated, but in new states of chemical union.

With regard to the distinction between the vegetable and animal compounds, the latter are more liable to decomposition from the re-action of their elements. The kind of spontaneous decomposition, too, which they suffer is different. They are scarcely susceptible of the vinous fermentation; they seldom even pass into the acetous, but undergo putrefaction, a process in which the principal products are ammonia, and certain compound elastic fluids having an offensive odour, by the formation and evolution of which the whole nearly of the original matter is dissipated. In their decomposition by heat, ammonia too is a principal product; prussic acid is usually formed, elastic fluids are disengaged, somewhat similar in chemical composition to those evolved in putrefaction, and the residual charcoal affords phosphoric salts.

These differences arise from the peculiarities in the composition of animal matter. Being more complicated than that of vegetable matter, or derived from the union of a greater number of elements, the affinities these reciprocally exert are more nicely adjusted; hence they are more easily subverted. They not only contain carbon, hydrogen, and oxygen, the usual constituent principles of vegetable matter, but likewise nitrogen in considerable quantity, and sulphur and phosphorus in smaller proportions. From the nitrogen existing in animal substances, is derived the abundant formation of ammonia which attends their decomposition, the nitrogen forming it by combining with hydrogen ; and its predominance in their composition is very well shewn by its evolution when they are acted on by nitric acid. The presence of sulphur and phosphorus is discovered, by their being contained in the elastic fluids disengaged during the putrefaction, or decomposition by heat of animal matter ; and it is the predominance of these principles which appears more peculiarly to give rise to the characters which distinguish putrefaction : the acids formed by their oxygenation are also found in the residual charcoal, combined usually with soda and lime. Carbon, it may be added, is contained in animal substances, in a proportion inferior to that in which it enters into the composition of vegetable products, and hence they give less carbonic oxide and carbonic acid in their decomposition ; they afford, too, less empyreumatic acid, a proof that oxygen exists in them in inferior proportion ; on th contrary, hydrogen appears to be predominant, from th large quantity of empyreumatic oil which they usually af ford.

The animal products are ultimately derived from chang produced in the composition of vegetable matter, all an mals living directly, or indirectly, on vegetable food ; an even the present imperfect state of chemistry enables to trace, in part, their formation,—the conveyance of the elements, and the processes by which these are broug into the combinations, whence the varieties of animal ma ter are formed. Vegetable matter is composed chiefly carbon, hydrogen, and oxygen; and can, therefore, furnish the whole of these elements which are required for the purposes of animal nutrition and growth. From the same source, or from the water with which the animal is supplied, may be derived the lime and iron, which are contained in small quantity in the animal products; at least the only supposed difficulty, with regard to these, is in the case of those animals by whom a large quantity of lime is secreted in the formation of their shells. There is a greater difficulty with regard to the source of the nitrogen, which is so abundant in animal matter; for although it is contained in some vegetable substances, it is not a common principle, and is usually in small proportion; and it does not appear that any portion of it is conveyed, as was once supposed, into the mass of blood, by respiration, from the atmospheric air. The present uncertainty, however, with regard to the nature of this substance, precludes nearly all satisfactory speculation on this subject. Phosphorus is another principle, the origin of which is not very obvious; it is always contained in animal substances, and even a considerable portion of it, in the state of phosphoric acid, is discharged as excrementitious; yet it is rarely found in vegetable matter. Still it has been shewn, that in those vegetables which are most nutritious, as in wheat, phosphorus is a constituent principle, the ashes of a pound of wheat-flour yielding 84 grains of phosphate of lime; and it is only in those animals who feed, in part at least, on animal matter, that the urine holds phosphoric salts dissolved. These facts lend probability to the supposition, that it is conveyed by vegetable food.

It is also sufficiently certain, that the vegetable analysis is not yet arrived at that state of perfection, that we can be certain that small portions of these principles may not exist in the composition even of every variety of vegetable matter; and that thus slowly introduced, they may accumulate in the animal system. And, with regard to the whole of this subject, it must farther be admitted, that the state of chemistry does not allow us to decide what substances are truly simple; and all those, with regard to which these difficulties have been supposed to exist, may either be compounds, or, if simple, it is equally possible, may exist in the composition of others, which our imperfect knowledge ranks as elementary.

The principles conveyed by the food, from which it is sufficiently evident, whatever difficulty we may have in tracing them minutely, animal nutrition is *ultimately* derived, are brought into those combinations productive of the several varieties of animal matter, by the united processes of digestion, respiration, and secretion; and the operations of these, so far as it can be done, it is satisfactory to trace.

In digestion, the food is submitted to the action of the gastric juice, or liquor secreted by the glands of the stomach, at a temperature, in the more perfect animals, above 90, and to the pressure, more or less forcible, arising from the contraction of the stomach itself. It is thus resolved into a soft pulpy mass, in which the previous texture or nature of the aliment can scarcely be distinguished. By facts, to be afterwards stated under the chemical history of the gastric fluid, it is proved, that it is principally by the solvent power which it exerts, that this digestion of the food is effected. The nature of the change itself is not very well ascertained; but the food does not seem to be resolved into its ultimate principles; its soluble parts rather appear to be extracted without decomposition, and brought into intimate mixture, while there is also a partial animalization, by the intermixture of the saliva and gastric fluids. The digested food, conveyed into the intestinal canal, probably continues to suffer further changes, promoted by the temperature, and alternating pressure; and more directly produced by the action of the pancreatic juice and the bile; after the intermixture of the latter fluid, traces of the chyle are observed, and this milky fluid, in the progress of the food through the intestinal canal, is absorbed by the lacteals, and conveyed into the mass of blood. Chylification, therefore, is the last stage in the process of digestion; the precise nature of the changes which constitute it are not ascertained, but, from the opaque milky appearance of chyle, it is obvious that it is not a perfect solution; the more soluble principles of the food are, no doubt, dissolved in it; others less soluble, but probably nutritious, appear to be suspended in it; and the whole is so far animalized, as to contain a product approaching to one of the most important principles of animal matter, albumen, capable of being discovered in it by coagulation by heat. The chyle mixes with the blood, so that all traces of it are immediately lost.

There is a chemical change constantly produced in the blood by the process of Respiration, probably connected with the process of animalization. While it circulates through the lungs, it is exposed, in the minute blood-vessels, under a very extensive surface, to the action of the atmospheric air, alternately taken in and thrown out in breathing. A portion of carbonic acid is formed, and discharged from the lungs, the quantity of oxygen necessary to form this, being abstracted from the atmospheric air inspired. The blood loses, therefore, a portion of carbon, with which this oxygen combines; and as this process is constantly carried on, it must be connected with the changes which the blood suffers in the system,—in other words, with the formation of the animal products. It is not improbable that a portion at least of this carbon is derived from the imperfectly assimilated chyle, and as animal matter contains a smaller proportion of carbon than vegetable matter, a portion of it probably remains redundant in the blood, after the formation of the *principles* of that fluid from the chyle, or of the other animal products in the course of the circulation; a principal office, therefore, of respiration, is probably to remove a principle which would thus otherwise become redundant.

Lastly, by Secretion the animal fluids and solids are formed. Either in the extreme blood-vessels, or in the minute and convoluted vessels which constitute the glands, the blood suffers changes of composition, whence the different products are formed. The nature of the process of secretion, by which this is accomplished, is extremely obscure; but it is evident, that however the actions of the vessels, whence the changes arise, may be dependent on their vitality, the changes themselves are strictly chemical. And it may perhaps be proposed, as no improbable hypothesis of the nature of secretion, that the cause productive of the new combinations to which it gives rise, is merely the approximation of the elements of the blood, by the contraction of the vessels through which it is transmitted. It is urged, by the contractile force of the heart and arterial system, through vessels extremely minute, and even the diameters of these vessels are alternately diminished and enlarged by their alternate contraction and relaxation. By this, an approximation and change in the relative positions of the particles which compose the principles of the blood must be produced. There can now remain no doubt, that the force of attraction between the minute particles of matter is materially modified by the distances at which they are placed; by such a cause, therefore, changes in the exertion of attraction in the principles of the blood may be produced, and be productive of all the new combinations to which secretion gives rise.

By secretion a variety of products are formed,—as the bile, milk, &c.; and by an analogous process, carried on without the intervention of glands, in the extreme blood-vessels, are probably formed the principles of the blood itself, and the greater number of the animal solids. The process of animalization is thus completed, and, from the progressive operation of these general processes, Digestion, Respiration, and Secretion, the formation of animal matter is traced.

CHAP. II.

OF THE ANIMAL PRODUCTS.

THE different varieties of animal matter may probably, like vegetable substances, be comprised under a certain number of well-defined species. This, however, is as yet imperfectly attained; we therefore consider merely the principal animal fluids and solids, introducing under their history those specific distinctions which can be established, and the notice of those principles which are characterised by these distinctions. The blood may first be considered as the source of the others; and its history is farther of importance, as it contains those proximate principles of which the other varieties of animal matter are principally formed.

SECT. I.—*Of the Blood.*

THE blood, or common fluid which circulates in the vessels of the animal system, and is the source of the various secreted products, differs in the different tribes of animals. It is from its properties in the more perfect, or warm-blooded animals as they are named, that its chemical history is drawn..

While in the vessels of the animal system, it appears to be homogeneous. The microscope discovers it, however, to consist of globules diffused through a liquid; and when it has been drawn for a short time, it separates into two parts, one solid and firm, of a red colour, the other liquid, of a slight yellowish tinge. The former is named the Crassamentum, the latter the Serum. By a farther simple analysis, that merely of washing with water, the crassamentum is resolved into two parts, a firm white elastic substance, insoluble in water, which has been named Gluten or Fibrin, and the colouring matter of the blood, which is carried off in a state of solution. The cause of the coagulation of the blood is not well determined. It takes place more readily when the temperature is allowed to fall, and when the blood is at rest; but it also happens when it is agitated, and when the temperature is not reduced. Neither is it dependent on the access of the air. It probably arises from a property belonging to the fibrin, the operation of which is counteracted by the circumstances under which the blood circulates in the animal system.

This coagulation affords the most simple and direct mode of discovering the immediate constituent principles of the blood.

The liquid portion, or Serum, is of a pale yellowish colour, somewhat tenacious, and has a slightly saline taste. It is perfectly miscible with water; a little free soda exists in it, whence it changes the blue colour of violet to a green.

It coagulates from the application of heat, raised to 160°, forming a mass more or less firm, but tremulous, with a portion of liquid diffused through it. It is also coagulated by the action of a number of the acids, by salts with an excess of acid, by alkohol, and by some metallic oxides. The substance which coagulates exists in many of the animal products, besides the blood. It is named Albumen, and is the first immediate principle existing in this fluid, the properties of which are to be pointed out.

Albumen is soluble in cold water, but is separated from it by coagulation when its temperature is raised, and also by the action of those re-agents which separate it from the serum. After its coagulation it is not soluble as before. The coagulation by heat does not take place when its solution has been previously much diluted. The alkalis dissolve albumen; ammonia dissolves it very slowly, the solution forming a kind of viscid porous pulp: potash and soda, while they dissolve it, partially decompose it, causing an exhalation of ammonia, and the separation of a grey powder. Acids likewise dissolve it, but at the same time re-act upon it, producing decomposition to a greater or less extent. It is decomposed by heat, and in this decomposition affords the usual products of the decomposition of animal matter. Sulphur appears peculiarly to exist in it; hence, when it is triturated with nitrate of silver, the sulphuret of the metal is formed.

The chemical test by which the presence of albumen can be recognised with the greatest delicacy and accuracy, is the corrosive muriate of mercury, a few drops of its solution detecting, by the milkiness it produces, albumen dissolved in 2000 parts of water. Goulard's Extract, and nitrate of silver, also precipitate it; but they are of little utility as tests, as they act on other principles of animal matter.

Albumen exists not only in the blood, but in many of the soft solids. Mr Hatchet's experiments prove that it forms the base of cartilage, shell, horn, and hair, and it enters into the composition of membrane, muscular fibre, and bone.

If the liquid diffused through the coagulum of the serum be pressed out from the albumen, and if it be made to boil gently, it has been said to become gelatinous on cooling. This being the distinguishing property of a principle existing in various animal solids, and denominated from it Gelatin, it has been inferred, that it is one of the constituents of the blood. The fact, however, has been more lately rendered doubtful by Dr Bostock's experiments. When the albumen of the serum is coagulated by heat, the separation is not perfect, a portion still being dissolved in the remaining liquid. But if this be removed by precipitation by oxy-muriate of mercury, it does not afford a jelly, and it gives no precipitate with infusion of tannin, a test by which gelatin is discovered in very minute quantity. Hence he concludes, that gelatin does not exist in the serum of the blood. There is a small quantity of an uncoagulable matter, however, different from albumen, which he considers as the principle denominated Mucus, the characters of which are not being coagulated by heat, nor concreting by cold, and not being affected by corrosive muriate of mercury, or tannin, but being copiously precipitated by acetate of lead.

The serum, besides these varieties of animal matter, holds dissolved some saline substances,—pure soda, muriate of soda, phosphate of soda, and phosphate of lime.

The Crassamentum of the blood is of a soft consistence, and a dark-red colour, which becomes florid at the surface from exposure to atmospheric air or oxygen gas, while it is rendered of a darker hue by other gases. Though apparently homogeneous, it is resolved, by the mere affusion of water continued sufficiently long, into two parts; the colouring matter is carried off in solution in the water, and there remains a white fibrous substance denominated Fibrin.

The colouring matter appears from microscopical observations to be in the form of round globules. It is soluble in water, retaining its colour; but when the solution is heated to 170°, it becomes brown, and a flocculent precipitate is formed. It is this matter on which the gases act more peculiarly; and substances capable of communicating oxygen to it, as oxide of mercury, when diffused through its solution, communicate to it a florid hue.

This colouring matter appears partly to consist of albumen as it is coagulated by heat, and by acids, while alkalis dissolve it. The matter communicating colour appears to have iron for its basis, either the pure colouring matter itself, obtained by evaporation of its solution, or the entire crassamentum, affording a considerable quantity of that metal in the residual matter obtained in its decomposition by heat. This is, according to the experiments of Fourcroy and Vauquelin, oxidated, and probably in the state of a sub-phosphate. The colouring matter obtained by evaporation of its solution, they found, afforded phosphoric acid and oxide of iron. Sub-phosphate of iron, according to these chemists, is of a brownish-red colour, and soluble in alkalis; and the pure soda of the blood, they suppose, maintains it in a state of solution. They accordingly affirm that sub-phosphate of iron is soluble in the serum of the blood, or in the white of an egg which is albumen nearly pure, and that it forms a deep red colour, the addition of a little pure alkali both promoting the solution, and rendering the colour more lively. Hence they conclude, that the colouring matter of the crassamentum consists of albumen with sub-phosphate of iron.

The Fibrin, which is its other constituent part, remains when the colouring matter has been removed by the affusion of water; it is also obtained by agitating the mass of blood itself with a rod, the serum and colouring matter being mixed by the agitation, while the fibrin adheres to the rod. It is sometimes found concreted in the large blood-vessels after death, forming what have been named Polypi; and in inflammatory diseases, it is more peculiarly disposed to separate from the blood when it is drawn from the vessels, and gives rise to the appearance named the Inflammatory Crust, or Buffy Coat of the Blood. The same principle exists in other animal products; it is in particular the basis of the Flesh, or Muscular Fibre.

Fibrin is a solid elastic substance, of a distinctly fibrous texture, of a white colour, inodorous and tasteless; it shrinks when dried and exposed to heat; it is quite insoluble in water, except at a very high temperature, obtained by applying heat under compression. In a humid state it is liable to spontaneous decomposition, softening, and at length becoming putrid. It is dissolved by the alkalis, but is at the same time decomposed, ammonia being exhaled when it is acted on by potash or soda. Pure ammonia scarcely acts upon it, unless heat be applied; it then dissolves it. The acids decompose it,—sulphuric acid charring it, and forming acetic acid,—nitric acid disengaging from it nitrogen gas, and forming other products which vary according to the concentration of the acid, the principal of which are, acetic, malic, and prussic acids, an oily substance, and a peculiar yellow bitter matter,—muriatic and acetic acid dissolving it, but so far changing its composition, that when it is precipitated by the alkalis, it no longer has its original properties. It is decomposed by heat, and affords the usual products of the decomposition of animal matter.

After this enumeration of the constituent proximate principles of the blood, the properties of the entire compound itself, which in a great measure result from these, will be better understood.

The blood, when newly drawn, appears homogeneous; it is soluble in water, and this dilution prevents its spontaneous coagulation. If it be heated, however, the albumen is partially separated in flakes. Acids added to blood immediately decompose it, rendering its colour dark, and producing coagulation. Alkalis render it more thin, and prevent its spontaneous coagulation. The metallic salts in general decompose and coagulate it. It soon passes into putrefaction; but if the watery part be dissipated by evaporation, and the solid matter be rendered perfectly dry, this change takes place very slowly. Decomposed by heat, it affords all the products of animal matter; the elastic fluids disengaged are extremely offensive, and the charcoal which remains is brilliant, and of difficult incineration; when burnt, it affords a considerable portion of iron.

In concluding the history of the blood, it is necessary to remark, that there is an important difference in it, as it exists in the arteries and in the veins of an animal; and this difference from the known operation of the cause by which it is produced, must depend on a chemical change. The venous blood returned from the extreme vessels to the heart, is brought by the pulmonary arteries to the lungs, through which it circulates, exposed to the air received in respiration, under a very extensive surface, and with the interposition of a very thin membrane, which appears not to prevent the reciprocal action of the air, and blood. Part of the oxygen of the inspired air, is consumed, and a portion of carbonic acid gas is formed, which is expired with the residual air; the blood at the same time loses its dark purple colour, and acquires a vivid vermilion hue; it is returned to the left side of the heart, is conveyed by the arteries to the different parts of the system, and again converted to the venous state. These reciprocal changes are so necessary to life, that their interruption by the suspension of respiration proves almost immediately fatal: they are obviously connected with changes of composition, and are hence subjects of chemical investigation.

Many experiments have been made to determine the relation between the consumption of oxygen by respiration, and the formation of carbonic acid, and the extent of these changes. These have presented very discordant results, particularly with regard to the proportion of oxygen consumed, to that of carbonic acid formed. By the late accurate experiments of Allen and Pepys, it appears to be established, that there is no excess of oxygen consumed above that which is necessary to the formation of the quantity of carbonic acid gas which is produced, as had been supposed, but that the one is equivalent to the other. The absolute quantities vary from circumstances, but on an average, they estimate the production of carbonic acid gas, in natural respiration, at 26.6 cubic inches in a minute; and as oxygen gas occupies exactly the same space, when converted into carbonic acid gas, which it does in its pure form, this of course gives the quantity of oxygen consumed in the same time. There appeared, in some prior experiments, to be also a consumption of nitrogen in respiration; they found, however, that this is not the case, and the apparent consumption is owing to fallacy from the effect of respiration rendered laborious in the course of the experiment; by which, at the end of it, the full proportion of air is not thrown from the lungs. A portion of watery vapour is also expired: its quantity amounts to between two and three grains in a minute, and its source is probably evaporation from the humid surface of the lungs.

The chemical changes which occur in respiration, are considerably influenced by various circumstances. Thus the consumption of oxygen is greater at a low, than at a high temperature; during digestion, its consumption is also increased, as it is by muscular exertion. When oxygen gas is respired, more of it is consumed than in the respiration of atmospheric air; and there is some reason to infer, that a portion of it is in this case absorbed by the blood.

Different views have been presented of the manner in which the chemical changes that occur in respiration are produced. Crawford advanced perhaps the first explanation that could be considered as precise. He supposed, that in the course of the general circulation, and more especially in the extreme vessels, the arterial blood receives a supply of the compound of carbon and hydrogen, which in its elastic form constitutes the heavy inflammable air of the older chemists, the hydro-carbon, or carburetted hydrogen of the modern nomenclature; by receiving this, it is converted to the venous state; this principle escapes from the venous blood during its circulation through the lungs, permeates the thin membrane in which the blood is inclosed, and combines in its nascent state with the oxygen of the inspired air, forming carbonic acid gas and watery vapour, which are expired. And the blood, losing this hydro-carbon, resumes its arterial state.

Lavoisier presented a similar view; at the same time he remarked, that the phenomena of respiration may be explained in another mode,—that the oxygen which disappears in respiration may be supposed to be absorbed by the blood; it may, in the course of the circulation, combine with carbon to form carbonic acid, and this acid conveyed by the venous blood, may be discharged in the lungs, while a new portion of oxygen is taken in. This explanation was adopted and illustrated by Hassenfratz and Lagrange.

Both these hypotheses are extremely defective. There is no proof in that advanced by Crawford, of carbon and hydrogen being communicated to the blood in the extreme vessels, or of the existence of such a compound as carburetted hydrogen in venous blood. And there is an equal deficiency of proof in the first principles of the opposite hypothesis, that oxygen is absorbed, or exists in arterial blood in a state of loose combination, or that carbonic acid is present in venous blood in a similar state: the last supposition seems even to be precluded by the fact, that when blood has absorbed carbonic acid, it is not rendered florid by subsequent exposure to oxygen. An objection to both hypotheses, not less important, is, that the changes which they suppose, are not analogous to the usual chemical changes which take place in the animal system; and that they are not sufficiently connected with the purposes which the blood serves in its circulation. When the *general facility* of combination in the principles of animal matter, and the tendency which the actions of the vessels have to form them into ternary or quaternary principles, are considered, it is improbable that oxygen should be absorbed by the blood in the lungs, without immediately altering its composition; that without being attracted by any of the other principles, it should be merely combined with carbon, or with carbon and hydrogen, in the proportions necessary to form carbonic acid and water; and that this carbonic acid, without affecting the ultimate composition of the blood, should be carried the whole length of the venous circulation, and thrown out at the lungs. It is equally improbable, that carbon and hydrogen should be brought into a state of binary combination in the extreme vessels, and should be held dissolved by the venous blood, till acted on by the oxygen of the air in respiration. Still less are the changes which these explanations suppose connected with the changes which the blood suffers. Its principles are expended in the formation of the different secretions, and in the nourishment of the solid fibre. But no connection is traced between these known changes, and the supposed communication of hydro-carbon, or the combination of carbon and oxygen, in the extreme vessels.

The conversion of arterial into venous blood ought to be considered as the result of the changes carried on in the extreme vessels, and this conversion, as well as that of venous into arterial blood, as arising from changes in the ultimate composition of the known proximate principles of the blood, and not from the alternate communication and abstraction of a principle which it holds dissolved in a state of loose combination. According to this view of the subject, the following may be considered as an explanation of these phenomena.

The blood is the source whence the products of the animal system are formed. Its expenditure is constantly supplied by the chyle, a fluid less completely animalized than the blood itself. The peculiar character of animal matter, with respect to composition, is a large proportion of nitrogen, and a diminished proportion of carbon. It may therefore be inferred, that in the extreme vessels, where the animal solids and fluids are formed, the general process will be the separation from the blood of those elements of which animal matter is composed; and that, of course, carbon, which enter more sparingly into their composition, will exist in the remaining blood in an increased proportion. This may be considered as the general nature of the conversion of arterial into venous blood. The oxygen of the inspired air acting on the extensive surface of blood in the lungs will abstract a portion of carbon, forming carbonic acid; and this gives rise to the conversion to the arterial state. The accumulation of carbon is thus prevented, and the due proportion of the elements of the blood preserved.

From the chemical changes which occur in respiration, has been derived the explanation of that uniform temperature which animals preserve, in general superior to that of the medium in which they live. It had been observed, that in different animals, the superiority of their temperature to that of the surrounding air, is greater according to the greater size of their lungs; whence it had been inferred, that respiration is the source of animal heat,—a conclusion which Dr Black confirmed by observing the analogy between this process and combustion, in the changes which are effected in the air.

Dr Crawford first explained this doctrine with precision, and established it by accurate experiments. He had previously shewn, that in general, when inflammable bodies combine with oxygen gas, a diminution of capacity takes place, whence there must be an evolution of caloric; and that in the combustion of charcoal, when carbonic acid is formed from the combination of oxygen with carbon, a large quantity of caloric is rendered sensible. It is evident, that since in respiration a similar consumption of oxygen and production of carbonic acid take place, there must be a similar evolution of caloric. He further ascertained by experiment, that the capacity of the blood changes when it passes from arterial to venous; and of course from venous to arterial; that of arterial being larger than that of venous blood, in the proportion of 1.030 to 0.892. On these facts he founded his admirable theory of Animal Heat. In respiration, a quantity of oxygen is combined with carbon, and carbonic acid is formed. Caloric must be evolved in consequence of this combination. But the blood is at the same time changed from venous to arterial, and by this change acquires a greater capacity for caloric. It therefore takes up the caloric which has been extricated by the combination; so that any rise of temperature in the lungs which would be incompatible with life is prevented. The arterial blood, in its circulation through the extreme vessels, passes to the venous state. In this conversion, its capacity for caloric is diminished, as much as it had been before increased, in the lungs: the caloric, therefore, which had been absorbed, is again given out; and this slow and constant evolution of caloric in the extreme vessels over the whole body is the source of its uniform temperature.

Besides the experiments from which this theory was directly deduced, it has been confirmed by others, in which the quantity of caloric rendered sensible by an animal is measured. Dr Crawford, and Lavoisier and La Place, found, that when an animal is confined in a vessel, contrived so as to measure the quantity of caloric which it gives to the surrounding medium in a certain time, and the quantity of oxygen consumed by the animal in that time, this quantity of caloric corresponds nearly to the quantity evolved from the combustion of carbonaceous matter, such as wax or oil, in the same quantity of oxygen.

This explanation is altogether independent on any particular theory of respiration. Whatever may be the nature of the differences between venous and arterial blood, it is proved by experiment, that the blood in these two states has different capacities for caloric; and on this fact the explanation of the origin of animal temperature depends. It is likewise the same, whether the combination of oxygen with carbon be supposed to take place in the lungs or in the course of the circulation, since from this combination the carbonic acid expired is derived; and whenever this takes place, there must be an evolution of caloric.

Transpiration is a function analogous to *respiration*, and gives rise to similar changes, though to a much less extent. Carbonic acid gas is exhaled from the skin with watery vapour, and oxygen is consumed. A small portion of acid, too, appears to be secreted by the cutaneous vessels.

SECT. II.—*Of the Chyle.*

CHYLE is the fluid taken up by the lacteals from the food which has been digested in the stomach, and conveyed into the intestinal canal. It is conveyed by the thoracic duct into the mass of blood, and is obviously the source whence the expenditure of matter in the formation of the animal products is supplied.

The chyle is of a white colour; its taste is sweetish. It is, from its milkiness, evidently heterogeneous; and, on standing, a portion of a thicker consistence, it is affirmed, separates and collects on the surface. After exposure for some time to the air, it becomes gelatinous, and at length presents a firm coagulum, semi-transparent, and of a light red tinge, under which is a portion of liquid, thin, and of the colour of milk. Besides this matter, which coagulates spontaneously, it contains a fluid that coagulates by heat.

The properties of this fluid have been, however, very imperfectly examined, owing, in a great measure, to the difficulty of procuring it in quantity sufficient to admit of an experimental investigation. It probably differs, too, according to the substances received into the stomach, these being frequently discernible in it in an unchanged state. Thus the colouring matter of indigo is discerned by the blue tinge it communicates, and musk by its strong and peculiar odour.

SECT. III.—*Of Milk, Sugar of Milk, Saccho-lactic Acid.*

MILK, the secreted liquid designed for the nourishment of young animals, though it differs somewhat in its properties in different species, appears to contain the same proximate principles, and, on the whole, to be essentially the same.

It is white and opaque, bland and sweet to the taste; its consistence is somewhat thick, and its specific gravity a little greater than that of water. On remaining at rest after it has been drawn, it soon suffers a slight decomposition; a thick bland fluid, the cream, rises to the surface, and the portion beneath remains rather more watery. This separation facilitates the examination of its proximate principles.

The Cream is of an oily nature. By agitation it is resolved into a fluid and solid part, the latter having the properties of expressed oil. This substance, Butter as it is named, is a constituent part of the milk, and appears to be in a great measure mechanically diffused through it.

Milk, after the separation of the cream has taken place, soon suffers another change; it becomes acescent, and then coagulates, apparently from the re-action of the acid on the principle that separates, as acids, even the weakest, have the same effect. It is also produced by a number of neutral salts, by alkohol, by the gastric fluid of animals, the juices of a number of plants, and even by heat; the matter which separates in films, when milk is heated, being the same as that separated by the action of these other substances. The gastric fluid taken from the stomach of young animals, or the liquid prepared from the maceration in water, with the addition of a little salt, of the membrane of the stomach itself, is usually employed to afford this matter in its least altered state.

The substance thus separated is the Cheese of milk, a principle having very peculiar properties. The cause of its separation is not ascertained, and it is rather singular that it should be occasioned by re-agents so different. The effect of the gastric fluid in separating it, does not depend on its acidity, as had been supposed; as, when it is not sensibly acid, or is even rendered alkaline, it retains the coagulating property.

The Cheese, or Caseous Matter of Milk, is white or greyish, somewhat elastic, insipid when fresh, though it acquires taste when kept. It is insoluble in water. Exposed to the air in a humid state, it soon passes into a state of putrefaction; but if rendered dry, it can be preserved long unchanged.

The fixed alkalis dissolve it, when their action is aided by a moderate heat, ammonia being at the same time exhaled from partial decomposition; and when an acid is added, sulphuretted hydrogen is evolved. The acids likewise dissolve it, but with more or less decomposition; nitric acid disengages from it nitrogen gas. Decomposed by heat, it affords empyreumatic oil, ammonia, and carburetted hydrogen; its residual charcoal affords small portions of fixed alkali and of phosphate of lime. These are the properties of cheese in its pure state. As usually prepared, it generally contains a portion of the oily matter of milk.

The Serum or Whey that separates from the coagulum of cheese, is a liquid of a yellowish colour and slight tenacity, and of a sweetish taste. When purified by filtration after the perfect separation of the cheese, it affords on evaporation a substance of a granulated appearance, sweet taste, and yellowish colour, which, dissolved in water, yields, on evaporation, rhomboidal crystals of a white colour. This substance, named the Salt or Sugar *of Milk*, is a very peculiar one. It is soluble in seven parts of cold, and four of boiling water. Decomposed by heat, it affords products the same as those from the decomposition of vegetable saccharine matter. Submitted to the action of nitric acid, aided by heat, nitric oxide is disengaged, and, as the mutual action proceeds, a copious deposition of a white substance takes place. The residual liquid contains oxalic acid.

The substance separated in this process has acid properties. It is named Saccho-lactic Acid. Scheele, by whom it was discovered, concluded that it pre-exists in the sugar of milk, combined with saccharine matter, and that the nitric acid merely developes it, *by decomposing* the sugar combined with it;—an opinion which, although it does not appear very probable, has been acceded to by Parmentier and Deyeux, in their researches on milk.

Saccho-lactic acid is in the state of a white granular powder; its taste is slightly sour; it is sparingly soluble in water, requiring 60 parts at 212° to dissolve it. This solution has an acid taste, and reddens the vegetable colours; it deposites small crystals on cooling. This acid forms, with the different salifiable bases, salts named Saccholates, of which those with the alkalis are soluble and crystallizable, those with the earths and metallic oxides of sparing solubility. This acid is likewise formed by the action of nitric acid on gum.

The whey of milk, from the quantity of saccharine matter it contains, can be made to pass into the vinous fermentation, so as to afford a weak vinous liquor. It passes more readily into the acetous fermentation; the acid which is formed when it becomes acescent, was once supposed to be a peculiar one, and was named the Lactic Acid. Later researches have shewn, that it is the acetic acid disguised by the presence of a little extractive matter, and of the small portion of saline matter contained in the whey. This matter consists of muriates of lime, potash, and soda, and phosphates of lime, magnesia, and iron.

The union of the saccharine and oily matter of milk, with the more animalized product, the cheese, render it a fluid at once nutritive and easy of digestion, and the presence of the phosphoric acid with the lime and iron adapt it to the formation of blood.

Sect. IV.—*Of Lymph.—Of Mucus.*

Lymph is a pellucid fluid taken up by the absorbents from the internal surfaces, or conveyed from the extremities of the arterial branches, and appears to be analogous to the serum of the blood. It is slightly viscid, is miscible with water, and coagulated by heat, by acids, and by alkohol.

The mucus, which covers the passages and internal cavities of the body, appears to be the lymph in an inspissated state, its watery portion having been absorbed. The term Mucus has been used, however, in a more appropriate sense, to denote a principle existing in the fluid which has usually received that name, as well as in other animal fluids. The characters assigned to it are solubility in water, its solution neither coagulating nor becoming gelatinous when heated; but by evaporation it can be obtained solid, and be again dissolved. It is not precipitated by tannin, or by corrosive muriate of mercury, but gives a copious white precipitate with Goulard's extract. It is insoluble in alkohol.

This principle appears to form the mucus of the nostrils,—a fluid which, as it is first secreted, is liquid and clear, but, from exposure to the air, becomes thick and viscid; and, by the continued action of oxygen, becomes nearly concrete, a change that is at once produced in it by oxy-muriatic acid. In this state it is not soluble in water, nor easily diffused in it; the acids thicken it, but in larger quantity re-dissolve it. The alkalis do not exert on it any solvent power. It contains a quantity of saline matter, principally muriate and carbonate of soda, and phosphates of soda and lime.

The liquid which forms the tears, Fourcroy and Vauquelin have observed, is nearly the same, and, like it, contains carbonate of soda, so as to change the colour of violet to green, with muriate of soda, phosphate of soda, and phosphate of lime. The latter, when it accumulates, forms the basis of the concretions sometimes found in the lacrymal glands.

SECT. V.—*Of the Saliva, and the Pancreatic Fluid.*

THE Saliva, or liquor secreted by the salivary glands, and designed to facilitate the mastication of the food, is slightly viscid, and has a taste very slightly saline; it does not mix uniformly with water; exposed to the air, it becomes more thick and turbid. When the liquid, formed by triturating it with water, is exposed to heat, it is slightly coagulated, and it suffers the same change from alkohol, and the stronger acids, denoting the presence of albumen. The fixed alkalis dissolve it, and disengage a small quantity of ammonia, by decomposing the ammoniacal salts it contains. Lime-water throws down from it a precipitate of phosphate of lime, and oxalic acid detects lime in its composition. Acetate of lead, and other metallic salts, produce a copious precipitate from their action partly on the mucus, partly on the saline matter it contains. Evaporated by a gentle heat, it affords crystals of muriate of soda, and crystals similar to those of muriate of ammonia; and when decomposed by heat, its residual charcoal yields, by incineration, muriate of soda, phosphate of soda, and phosphate of lime.

The concretions which sometimes form in the salivary glands, consist of phosphate of lime with animal matter, probably inspissated mucus, or albumen. The incrustation which forms on the teeth, is of a similar nature.

The liquor secreted by the Pancreas, and apparently designed, like it, to facilitate the changes which the food is to undergo, is similar, in its sensible qualities, to saliva; and, on evaporation, affords, like it, crystals of muriate of soda, and a colourless mucus, partially soluble again in water. It is colourless, and has a taste slightly saline.

SECT. VI.—*Of the Gastric Fluid.*

THE liquid secreted by the glands of the stomach, and subservient to the process of digestion, operates probably by its chemical agency; and hence the importance of the investigation of its properties;—an investigation rendered difficult, however, from the difficulty of obtaining it pure in any considerable quantity. Spallanzani, by whom the operation of the gastric fluid, as connected with the process of digestion, has been laboriously investigated, *observed that this* fluid, whether procured from the stomach of gramenivorous or carnivorous animals, appeared to be the same in physical qualities. If unmixed with any of the food, it was clear, its taste was slightly saline; it gave no indication of acidity, except sometimes when obtained from animals feeding on vegetable food, from changes in which, the acid was probably derived. Neither was it sensibly alkaline. On adding nitrate of silver, it gave a precipitate of muriate of silver. Vauquelin found in it phosphates, and free phosphoric acid, and a small quantity of albumen was separated from it by the action of acids. Spallanzani observed, that it is liable to putrefaction, that it preserves other substances from becoming soon putrid, and even restores the sweetness of animal matter which had become putrid,—observations to a certain extent confirmed by Stevens, though Vauquelin observed that the gastric fluid which he examined became corrupted in a few days.

The most remarkable property of this fluid, and one which must be regarded as depending on its chemical agency, is the solvent power which it exerts on the food. Reaumur observed, that if the food on which an animal naturally subsists be inclosed in metallic tubes, so as to protect it from any muscular action of the stomach on it, but perforated so as to admit of the action of the gastric fluid, it is dissolved, in those animals particularly who have a membranous stomach, and live on flesh; but in those who have a muscular stomach, susceptible of strong contraction, the solution was much less complete, or even frequently scarcely effected. This obviously might arise from the trituration produced in the food by the muscular action of the stomach in those animals, facilitating the solvent action of the gastric fluid; and, accordingly, Spallanzani found, that when the food was previously bruised, and introduced into the stomach inclosed in tubes, it was dissolved. The solvent power, however, he found to be exerted in a much shorter time in those animals who have a membranous, than in those who have a muscular stomach; and in some of the former this power is very great, the hardest bone, for example, inclosed in a tube, being speedily dissolved in the stomach of the eagle, or of the dog. He likewise found, that the same solvent power was exerted by the gastric fluid out of the body, at a temperature not higher than that of the animal system. His experiments are confirmed, in general, by those of Stevens. The only discordance is, that Stevens found those kinds of food on which animals do not naturally subsist, are not dissolved by the gastric fluid of their stomach; while Spallanzani found, that in animals who feed naturally on flesh, grain previously bruised is dissolved, and in those who feed on grain, flesh undergoes solution. The animals, however, on whom he made these experiments, do not appear to be naturally much limited with regard to the food on which they subsist; and some animals, birds of prey for example, Spallanzani admits, were incapable of digesting vegetables. It appears on the whole, therefore, that the solvent power of the gastric fluid is in a great measure exerted only on the food natural to the animal; though in many species the stomach appears to be capable of adapting itself, to a considerable extent, to the substance which it receives, so that an entire change can at length be effected in the habits of many animals, with regard to the food on which they can subsist. In those who feed both on animal and vegetable substances, both are dissolved by the gastric fluid.

The solvent power of this fluid is very well shewn in its action on the stomach itself, which, in carnivorous animals especially, who die suddenly, and in a state of vigour, is sometimes found, a few hours after death, to be partially dissolved in its depending part,—a fact, too, which well shews how far the presence of vitality suspends the usual laws of chemical action, since it protects the stomach from the action of a liquid thus capable of dissolving it. Stevens, however, has, from some observations, supposed that this is to be received with some limitation, and that animals, even when alive, are in some cases subject to the powers of digestion.

These properties of the gastric fluid cannot be traced to any obvious chemical property of which it is possessed, or to the known, or even the probable agency of any principle which it contains, and are therefore, with regard to our knowledge of it, altogether anomalous.

SECT. VII.—*Of Bile, and Biliary Calculi.*

BILE, the liquor secreted by the liver, is probably in part excrementitious, and in part designed to promote the process of digestion, or rather of chylification, no traces of chyle being discoverable in the digested food, until after its intermixture with the bile. It has the singularity of being secreted from venous blood, and with this is probably connected its peculiar composition, in which carbon and nitrogen appear to predominate. It has even been supposed to convey the excess of these principles from the system, and its secretion therefore has been considered as subservient to the process of respiration.

As first secreted, it is liquid, and in this state it in part flows into the intestinal canal. A portion of it is received into the reservoir named the Gall Bladder, in which it suffers a degree of inspissation; and it is this Cystic Bile, as it has been named, which has been usually submitted to chemical examination. It is thick, and of a specific gravity greater than that of water; its colour is greenish-yellow; its odour faint; its taste intensely bitter. It suffers, in a short time, spontaneous decomposition, and acquires an offensive odour.

Bile, evaporated by a gentle heat, affords a large quantity of water, having its smell, but not its taste. The residual matter, Extract of Bile as it is named, is thick, of a dark-brown colour, deliquescent, and soluble in water. It cannot be rendered concrete without decomposition, and when decomposed by heat, affords a liquid brown and fetid, sulphuretted hydrogen, carbonate and acetate of ammonia, empyreumatic oil, and carburetted hydrogen, with carbonic acid; its residual charcoal affording much carbonate of soda.

Bile is soluble in water in every proportion, and its solution changes the colour of violet to a green, indicating the presence of a free alkali.

It is decomposed by the acids, a precipitate being thrown down of a greenish colour, and the bitter and inflammable matter of the bile remaining in solution. Alkohol produces a similar effect more completely, and affords the most direct mode of separating the proximate principles of this fluid. The coagulum which it forms, when collected on a filtre and washed, is a white viscid substance, having scarcely any bitterness, very putrescible, and approaching very nearly in its properties to albumen. The same substance is separated, though less perfectly, by heat. The filtered liquor retains the colour and the bitterness of the bile. By evaporation, it affords a concrete substance, inflammable, fusible at 120, soluble in alkohol, and precipitated from this solution by the affusion of water. From these properties it has been named the Resin of the Bile, and is evidently the principle in which its chief properties reside. The solution contains, likewise, a portion of soda; and this soda is equally discovered in the coagulation of bile by acids, the salt which soda forms with the acid employed in the experiment remaining in the liquor from which the albumen has been precipitated.

Besides these principles, there exists in bile a species of saccharine matter, approaching in its properties to Sugar of Milk. Cadet obtained it by the simple process of decomposing bile by muriatic acid, and evaporating the residual filtered liquor, so as to cause it to crystallize. Along with crystals of muriate of soda, crystals of a different form of this peculiar matter were obtained. Thenard having obtained it by a more complicated process, in what he supposes to be a state of greater purity, found it to be soluble in water and in alkohol; it does not ferment with yeast, gives no ammonia by distillation, and is not affected by infusion of galls. It contributes, he supposes, with the portion of soda which bile contains, to the solution of the resinous matter; these three principles forming a ternary compound, which, with a little albumen and some saline matter, constitute bile. The salts are muriate, sulphate, and phosphate of soda, and phosphate of lime, with a little oxide of iron. The proportion of resinous matter in 1000 parts is, according to Thénard's analysis, about 43, of saccharine matter 41, of albumen 4, soda 4, of the above neutral salts 5.5, oxide of iron 0.5.

THERE are often found in the receptacle of the bile, the gall-bladder, concretions, or Biliary Calculi. These are not always uniform. Those most common are of a lamellated structure, and are composed of a substance analogous to the animal fat, named Spermaceti, or rather to the substance which has been named Adipocire, and of which spermaceti is a variety. This matter is fusible by heat; it is soluble in alkohol, when a boiling heat is applied, but precipitates in brilliant scales as the solution cools: It is also soluble in ether, when heat is applied; and potash and soda dissolve it, forming a kind of saponaceous compound. It forms the substance of the biliary calculi, in which it exists, disposed usually in crystalline laminæ, more or less mixed with a yellowish or greenish matter, which is probably inspissated bile; in some this matter predominates, so that the adipocire is discovered only by its deposition, when the concretion has been dissolved in boiling alkohol. And sometimes the calculus consists of alternate layers, formed of mixtures of these in different proportions.

SECT. VIII.—*Of Urine, Urée, Uric Acid, Urinary Calculi.*

THE fluid secreted from the kidneys, contains more saline substances than any other secreted fluid; these it is probably designed to convey from the system: there is also dissolved in it an animal principle, which gives to it peculiar characters.

When newly secreted, its colour is pale, its odour peculiar, but not fetid; it is transparent, but usually becomes turbid as it cools. It is sensibly acid, reddening the infusion of litmus. But, from the spontaneous changes it suffers producing ammonia, this acidity is soon neutralized, and it even becomes alkaline. These changes continue to proceed, mucous flakes are precipitated, the ammoniacal odour becomes strong and fetid, and the whole of the animal matter is at length decomposed, being converted principally into ammonia, combined with carbonic and acetic acids.

When urine is exposed to a gentle heat, its watery portion is dissipated, and with this carbonate of ammonia is formed and disengaged, the quantity increasing as the temperature rises. The liquid becomes turbid and deep-coloured; and when it is reduced to the consistence of thin syrup, it passes, on cooling, to the state of a confusedly crystallized mass; a liquor remains, very dark-coloured, holding the peculiar animal matter of urine dissolved.

The free acid existing in urine newly discharged, is principally the peculiar acid named Lithic or Uric Acid; it is often so abundant, as to be in part deposited, forming the reddish sediment deposited as urine cools; with this there is generally present a portion of phosphoric acid, and, as Thenard states, of acetic acid. A small quantity of benzoic acid is also often present, particularly in the urine of children, and of gramenivorous animals, in which case the uric and phosphoric acids are usually deficient.

All these acids, by the generation of ammonia, are speedily neutralized, and exist in the state of the salts which they form with that alkali, together with carbonate and acetate of ammonia, formed by the spontaneous decomposition of the urine.

Besides these, several neutral salts exist in urine. These are obtained by evaporation in a crystallized state, forming a saline matter, named by the older chemists Microcosmic Salt. This consists of a number of salts, phosphate of soda, phosphate of ammonia, phosphate of magnesia, phosphate of lime, muriate of soda, muriate of potash, muriate of ammonia, and the triple compounds of phosphate of soda and ammonia, and phosphate of magnesia and ammonia. These exert mutual affinities, which modify their properties, and render their entire separation difficult. They probably do not all pre-exist *in the urine*; those in particular which contain ammonia, derive a portion of it at least from what is formed by the combination of its elements during the evaporation. The quantities of them are of course liable to be varied according to the state of the secretion, and the time during which the urine has remained in the bladder. According to Mr Cruickshank's experiments, 36 ounces of urine yield an evaporation from one ounce to one ounce and a half of solid matter, consisting, on an average, of muriates one drachm, of phosphates nearly four drachms, uric acid and super-phosphate of lime twenty-five grains, animal matter three drachms and forty grains.

When the entire matter obtained by the evaporation of urine is urged by a strong heat, it affords a large quantity of carbonate of ammonia, accompanied with a fetid oil, and with elastic products. Muriate of ammonia is sublimed, and towards the end of the distillation, a small portion of phosphorus disengaged from the decomposition of the phosphoric salts is volatilized.

The action of re-agents on urine affords some information with regard to the principles it contains, which renders its analysis more perfect. The acids have not much effect on it in its healthy state; they sometimes coagulate or render it milky, an effect indicating the presence of albumen, from a morbid state of the secretion. Oxalic acid gives a precipitate by combining with the lime it contains. If much loaded with the animal matter named Urée, nitric acid throws down a scaly, pearly precipitate. The fixed alkalis precipitate phosphate of lime; the solutions of lime, barytes, and strontites, or of any of their soluble salts, produce more copious precipitates, as they decompose all its phosphoric salts, and form with the phosphoric acid insoluble compounds. The nitrates of silver, and of lead, form precipitates, from the metallic oxide combining both with the muriatic and phosphoric acids of urine. Infusion of tannin generally occasions a cloudiness in urine, indicating the presence of a little gelatin, and in some morbid affections, produces even a copious precipitate.

Besides the saline substances contained in urine, there exists in it a peculiar principle, which giving it some of its most characteristic properties, has been named URÉE. It remains in a great measure in solution, when the saline matter has been separated by crystallization; and some of its properties had been observed by Rouelle. His observations had been neglected until its existence and properties had been again pointed out by Mr Cruickshank, who gave the process for obtaining it in its crystallized form, by the action of diluted nitrous acid on the extractive matter of urine. Fourcroy and Vauquelin observed its production in the same experiment, and they gave also another process, by which it is more directly obtained, and without any ground for the suspicion that it is formed in the process. To the crystallised mass obtained by the evaporation of urine, there are added four times its weight of alkohol in successive portions, heating them gently. The solution contains the urée; it is distilled until of the consistence of syrup; and in cooling, this deposites the urée crystallized in quadrangular plates of a brilliant yellowish-white colour.

This substance exhales a strong urinous *odour*; it has a smooth greasy feel, attracts humidity from the air, and becomes liquid; dissolves readily in water, and dissolves also, though more sparingly, in alkohol; if its solution has been made with the aid of heat, it crystallizes on cooling. So susceptible is it of decomposition from the re-action of its principles, that its watery solution passes quickly into a kind of fermentation, analogous to the acetous, a disengagement of carbonic acid gas takes place, and acetic acid with a portion of ammonia are formed. If the solution is submitted to distillation, the urée, by adding fresh quantities of water, and repeating the distillation, is almost entirely converted into carbonate of ammonia. If the solid urée be exposed to heat, it melts quickly, carbonate of ammonia sublimes, and this continues without any condensation of water, or production of empyreumatic oil, farther than a minute portion that tinges the salt brown, and gives it a fetid odour. The carbonaceous residuum, after it has been urged by a strong fire, gives by lixiviation a liquor containing prussic acid, and when burnt in the open fire, yields a saline matter, principally carbonate of soda. Carburetted hydrogen, carbonic acid, and nitrogen gas, are disengaged. During this decomposition, urée is thus by the new combinations established among its principles by an elevated temperature, converted almost entirely into carbonate of ammonia; these elements must of course be carbon, oxygen, nitrogen, and hydrogen; the proportions it can scarcely be possible to estimate with any precision.

The acids act peculiarly on urée. Sulphuric acid diluted decomposes it when aided by heat, forming from its elements a portion of oil, acetic acid, and ammonia, and precipitating charcoal. Nitric acid, parting with oxygen so readily, might be expected to decompose rapidly a substance so susceptible of decomposition; yet what is singular, it appears rather merely to combine with it. When the acid is added to a strong solution of it, there is an instant deposition of crystalline scales, white and brilliant, which augments rapidly; this, when heated gently, softens and melts, an effervescence takes place, and it is converted principally into nitrate of ammonia. Hence Fourcroy and Vauquelin concluded, that it is a compound of nitric acid and urée. If heat is applied, however, to favour the action of the acid, or if the strong acid is poured on concrete urée, decomposition takes place, nitric oxide, nitrogen, and carbonic acid gases are disengaged, with prussic acid; and a white or yellowish concrete matter remains, consisting principally of nitrate of ammonia. Muriatic acid has little effect on urée, precipitating it only from its solution in alkohol in brown flocculi; oxy-muriatic acid decomposes it, disengaging nitrogen and carbonic acid gases, and forming a concrete oily matter. The results of all these decompositions prove the predominance of nitrogen in the composition of this principle.

The alkalis dissolve urée; the fixed alkalis at the same time cause an evolution of ammonia, partly from the decomposition of ammoniacal salts mixed with it, and partly from the decomposition of the urée itself; carbonic acid and acetic acid are at the same time formed, and a concrete oily matter is separated.

Urée so far modifies the properties of a number of the neutral salts, as to cause them to crystallize, *under a form* different from that which their crystals usually assume. Its solution decomposes several of the metallic salts. Tannin changes the colour of its solution, but does not form with it any precipitate.

The tendency of this principle to pass to the state of ammonia, is probably occasionally the cause of morbid changes in the urine, and perhaps gives rise to the formation of urinary calculi, by neutralizing the acid which holds some of the substances usually contained in the urine dissolved. The predominance of nitrogen in its composition is a singular fact, and proves the developement of this element by the processes of the animal system, since its excess is thus discharged by an excrementitious fluid.

Uric Acid is a substance peculiar to urine and urinary calculi, and with these therefore its history is best connected.

Scheele discovered this acid as the principal ingredient of urinary calculi; he found, too, that it is always contained in urine, forming the reddish-coloured sediment which it often deposites. From forming the basis of stone of the bladder, it received the name of Lithic Acid; as a common ingredient in urine, it is named Uric Acid.

It is difficult to procure it pure. The process given by Dr Henry is to dissolve a calculus composed of it in a solution of potash; this solution is decomposed by muriatic or acetic acid; the uric acid is precipitated, and is washed repeatedly with distilled water, a few drops of liquid ammonia having been added to the first portion of water, to remove more completely any foreign matter from the acid. It is thus obtained in the state of a white powder, rough to the touch, and tasteless. It is so sparingly soluble in water, as to require nearly 2000 times its weight at 60° to dissolve it; at 212° it is soluble in little more than 1000 parts, and this solution, on cooling, deposites minute pellucid crystals. It reddens infusion of litmus, decomposes soap, and precipitates the alkaline sulphurets,—properties sufficient to characterize it as an acid, though some chemists have been inclined to rank it as an oxide. It is so weakly acid as to be incapable of decomposing the alkaline carbonates, nor is it dissolved by their solutions.

Uric acid combines with the alkalis and earths, forming compounds in general of sparing solubility, tasteless, and scarcely to be distinguished in external appearance from the acid itself. The urate of ammonia is most soluble, and even of it an ounce of distilled water does not dissolve more than 2 or 3 grains at 60° ; next to it in solubility is the urate of potash. The alkaline urates become more soluble with an excess of base; and hence they are dissolved by boiling in an alkaline solution. These compounds, whether neutral or with an excess of base, are decomposed by all the acids, even the weakest, as the carbonic or prussic; they are decomposed, too, by almost all the neutral salts.

Uric acid is decomposed by the mineral acids; sulphuric acid chars it. Nitric acid has a singular effect upon it, affording a test which serves to distinguish it. It produces with it, when not added in excess, a red colour; this is deep when the mixture is concrete; it is also communicated to water in solution, but is destroyed both by alkalis and by acids. When nitric acid is repeatedly distilled from uric acid, it decomposes it, carbonic acid and nitrogen gases are disengaged, and prussic acid and nitrate of ammonia formed. Muriatic acid has little effect on uric acid; oxy-muriatic acid decomposes it, producing principally ammonia and carbonic acid.

Uric acid is decomposed by heat, affording carbonate of ammonia, carbonic acid, carburetted hydrogen, prussic acid, and a peculiar matter which sublimes and condenses in a concrete form. This substance has the properties of an acid, but is different from the uric acid. Its taste is slightly sour and bitter; it is much more soluble in water; it is volatilized by a moderate heat without decomposition, and it does not give a red colour with nitric acid. It is sparingly soluble in alkohol. Its solution in water reddens infusion of litmus. By evaporation it affords minute crystals; it combines with the alkalis, and is not precipitated from these solutions by the acids; neither does it precipitate the earthy salts. In some of its properties it is analogous to succinic, in others to benzoic acid; but still it differs from either, and from every known acid. When decomposed by the application of a strong heat, it affords products similar to those from the decomposition of uric acid, and is no doubt formed from an alteration in the state of combination of these elements, produced by the heat by which it is sublimed.

The composition of the urine varies in the different species of animals. In those who feed on grass, the uric acid is wanting, while benzoic acid is generally present; and this is also frequently the case in the urine of children. The urine of the horse, cow, and camel, contains no phosphates, but muriates, sulphates, and carbonates, with urée.

URINARY CALCULI owe their formation to deposition from the urine, or morbid changes in its secretion; and the investigation of their chemical constitution and properties is therefore connected with its history. It is one of much importance, from its relation to the discovery of the means by which their formation may be prevented, or by which they may be removed.

These concretions are not uniform; they differ much in their physical qualities, and it has been discovered that they differ not less in their chemical nature. The following substances enter into their composition; uric acid, urate of ammonia, phosphate of lime, phosphate of ammonia and magnesia, oxalate of lime, silex, and animal matter; these substances being more or less pure, or mixed, and being often diversified by mechanical structure, so as to render it difficult to reduce these concretions to well-defined species.

Dr Wollaston has reduced them to four species; *1st*, that composed chiefly of uric acid; *2d*, what has been named the Fusible Calculus, composed chiefly of phosphate of ammonia and magnesia; *3d*, The Mulberry Calculus, as it has been named by surgeons, consisting of oxalate and phosphate of lime; and, *4th*, The Bone-Earth Calculus, formed almost entirely of phosphate of lime. Fourcroy and Vauquelin have given a classification more minute and complicated, but not strictly chemical, calculi being admitted as species, from mere differences *in mechanical* structure.

1st, Uric Acid Calculus. This is by far the most common. These calculi are of a brown or yellowish colour, smooth, displaying internally a fibrous or radiated structure, and often in fine layers of different shades, rather soft and brittle, with a specific gravity from 1.276 to 1.786. They are not melted by heat, but charred, exhaling an empyreumatic odour. They are insoluble in cold water, but dissolve when boiled in water. Alkaline solutions dissolve them readily in the cold, and a white precipitate is thrown down by the addition of an acid. Lime-water dissolves them more sparingly. Nitric acid produces the red colour characteristic of uric acid; the other acids act weakly on them. In many the uric acid is nearly pure, in others it is intermixed with other ingredients. A calculus has been supposed to exist of urate of ammonia; but, from Mr Brande's observations, the ammonia which it exhales under certain trials arises from the decomposition of urée, or of phosphate of ammonia. It is less sensibly striated, and its colour is lighter than the pure uric acid calculus; and it is distinguished by the chemical character of dissolving in alkaline solutions, and exhaling a smell of ammonia, two properties which are not found together in any other species.

2d, Calculus of Phosphate of Magnesia and Ammonia. Fusible Calculus of Wollaston.—Phosphate of magnesia and ammonia seldom forms an entire calculus. It is either, if pure, discharged under the appearance of a white sand composed of minute crystals, or it is intermixed with other ingredients, particularly with uric acid and phosphate of lime, and frequently forms alternate layers of these, or covers a nucleus of uric acid. It is distinguished by its softness and smoothness, its white colour, its lamellated texture, and its giving a fine powder of brilliant whiteness. Before the flame of the blowpipe it melts into a white enamel; is charred when placed on burning fuel, and emits an ammoniacal smell; on raising the heat it melts. It dissolves very sparingly in boiling water. The acids, even those that are weak, dissolve it easily, leaving any animal matter mixed with it undissolved. The fixed alkalis disengage its ammonia, combine with its acid, and precipitate the magnesia.

3d, Calculus of Phosphate of Lime. This sometimes composes the entire substance of a concretion, though more frequently it is mixed either with uric acid or with phosphate of magnesia and ammonia, or disposed with them in layers. When pure or little intermixed, the concretion is of a pale brown colour, and so smooth as to appear polished; its texture is laminated. It dissolves slowly, but entirely, in muriatic or diluted nitric acid, and it is little affected by alkaline solutions. Before the flame of the blowpipe it is at first charred, but soon becomes white; and, if the heat be raised as high as possible, is fused.

4th, Calculus of Oxalate of Lime. This has been long known by the name of Mulberry Calculus, from its colour and its rough painted surface. Dr Wollaston shewed that it consists chiefly of oxalate of lime, with animal matter. It is of a dark brownish or purplish colour externally, often grey within; its surface is usually uneven, often covered with protuberances: it is the hardest and the heaviest of the urinary calculi. It is also less affected than any of them by the usual re-agents. The alkaline solutions do not affect it, and the stronger acids,—the nitric and muriatic dissolve it only with great difficulty. The solutions of the alkaline carbonates decompose it, precipitating carbonate of lime. It is also decomposed by heat, leaving, when urged by a strong fire, pure lime amounting to about one third of its weight.

In all these calculi, besides the saline matter of which they chiefly consist, there is present a portion of animal matter, which appears to give them colour and induration; it is found even in those which are white and crystalline; in the mulberry calculus, it is present in larger quantity than in the others. According to Fourcroy and Vauquelin, it is analogous to albumen, with frequently a mixture of urée. The ingredients of calculi are often also diversified by intermixture in layers more or less distinct. These must of course be various, and as their production is in some measure accidental, irregularly arranged. Those which have been most frequently observed, are alternations of uric acid with phosphate of magnesia and ammonia, or phosphate of lime; or of oxalate of lime with the uric acid, or with either or both these phosphates.

An important subject of investigation, arising from our knowledge of the nature of these concretions, is that relating to the practicability of their solution, and the means by which this may be accomplished. The internal administration of alkalis, with this view, is a practice that has long been had recourse to; and it has been sufficiently ascertained that the urine may thus receive, to a certain extent, an alkaline impregnation, and that from this considerable relief is obtained. It has farther been supposed, that with regard to some calculi, at least those in which uric acid is predominant, and which are by far the most common, a real solvent power may be exerted; and from the continued use of alkalis, a solution of the calculus, if it is of a moderate size, may be obtained; the solution of the calculus of phosphate of ammonia and magnesia, and that of phosphate of lime, it has on the other hand been supposed, might be effected by the administration of an acid.

So far as relieving the pain and irritation which attend stone in the bladder, the advantage derived from the moderate use of alkaline remedies is unquestionable. But there is every reason to doubt of the practicability of employing them so as to obtain the actual solution of a calculus; the degree of alkaline impregnation which the urine can receive is so inconsiderable, and the irritation produced, both in the stomach and bladder, by the alkali taken to this extent, so great, that its use cannot be continued for any length of time. Besides this, the recent observations of Mr Brande have placed in a still clearer light the impracticability of the attempt; for in rendering the urine alkaline, so as to enable it to act on the calculus, there is the risk of causing the deposition of phosphate of ammonia and magnesia, or phosphate of lime. On the other hand, the solution of a calculus of either of these could not be attempted, by rendering the urine acid, without the hazard of producing a precipitate of uric acid; nor is it probable that the alternate exhibition of these could be so adjusted as to produce any beneficial effect. All that is practicable probably is, the giving the alkali so far as to render the urine less irritating, and thus alleviate the pain.

SECT. IX.—*Of the Synovia.*

THIS name is given to the liquor found within the capsular ligaments of the joints, the motions of which it is evidently designed to facilitate. It is viscuous, of a greenish colour, and more or less transparent: when withdrawn from the capsule, it becomes gelatinous; after some time it loses this consistence, and deposites a fibrous elastic matter. It mixes easily with water, rendering it viscuous. Acids added to it throw down a flocculent precipitate, without diminishing the viscosity; but, when much diluted, they remove it; the liquor becomes thin and transparent, and a fibrous-like substance is precipitated.

This fibrous matter has properties analogous both to albumen and fibrin, yet still it differs from both. It is similar to the gluten of wheat in colour, taste, and odour, in tenacity and elasticity; it is soluble, however, by agitation in cold water.

There remains, after its precipitation, a portion of albumen, which may be separated by heat, or by alkohol; and when this is withdrawn, the residual liquor gives crystals of muriate of soda by evaporation. Its residual matter, when it is decomposed by heat, gives muriate and carbonate of soda; and its charcoal, by incineration, affords phosphate of lime.

Margueron, by whom it has been analysed, concludes that 100 parts of synovia contain 11.8 of fibrous matter, 4.5 of albumen, 1.75 of muriate of soda, 7 of carbonate of soda, and 7 of phosphate of lime.

Arthritic Concretions, or those concretions often deposited in the joints during a paroxysm of the gout, are probably formed by the medium of this fluid. Dr Wollaston found unexpectedly that they consist of urate of soda, as they had been supposed to be phosphate of lime.

SECT. X.—*Of the Amniotic Fluid.*

THIS fluid, with which the fœtus is surrounded in the amnios, is entitled to notice, as having afforded to Vauquelin what he has regarded as a new acid. The amniotic liquor of the cow is that which he examined; it is slightly viscid, has a reddish colour, an acid and bitter taste, and a faint odour. It reddens the more delicate vegetable colours. On evaporation, it forms brilliant crystals, coloured by a little animal matter, which may be removed by washing with a little water, and crystallizing again.

These crystals are the Amniotic Acid. It is white and brilliant, has a slightly sour taste, reddens infusion of litmus, is sparingly soluble in cold water, but dissolves more abundantly in hot water. It is also soluble in alkohol. It combines with the acids, forming peculiar salts, which are soluble. It does not decompose the alkaline carbonates, unless when aided by heat; nor does it precipitate the earthy salts, or the nitrates of silver or lead. It is decomposed by heat, exhales ammonia and prussic acid, and leaves a bulky charcoal.

It is singular, that the human amniotic fluid contains none of this acid, but consists of albumen and gelatin dissolved in water, with muriate and carbonate of soda, and phosphate of lime.

Sect. XI.—*Of the Humours of the Eye.*

The ball of the eye contains three fluids,—the Aqueous Humour, in the anterior chamber; the Crystalline Humour, or Lens, in the central space; and the Vitreous Humour, occupying the space behind the lens. They differ in their physical properties, but little in their chemical nature.

Aqueous Humour is a clear transparent liquid, having little smell or taste. It causes little change in the vegetable colours; exposed to the air at a moderate warmth, it evaporates, and a coagulum is formed, so small as hardly to be perceptible. Evaporated to dryness, it leaves a matter weighing not more than 8 *per cent.* of the original liquor. Tannin causes a precipitate in the fresh humour, both before and after it has been boiled, shewing the presence of gelatin. Nitrate of silver causes a precipitate, which is muriate of silver. It appears, therefore, that the aqueous humour is composed of water, albumen, gelatin, and a muriate, the basis of which is soda.

Crystalline Humour. This is solid, and composed of concentric lamellæ, which appear to become more dense towards the centre. The mean specific gravity is 1.100. When fresh, it is neither acid nor alkaline. It putrefies rapidly. It is nearly soluble in cold water, and is partly coagulated by heat. Tannin gives an abundant precipitate; but there are no traces of muriatic acid. It is composed, therefore, of less water than the others, but of a larger proportion of albumen and gelatin, and also a little phosphate of lime.

Vitreous Humour. This being pressed through linen, to free it from its capsules, Mr Chenevix could not, in that state, by all the experiments he made on it, perceive any difference between it and the aqueous humour, either in specific gravity, or in its chemical nature.

Sect. XII.—*Of the Skin, Cellular Fibre, and Membrane.*

The soft solids enumerated in the title of this section are closely connected, having the principle named Gelatin principally for their basis. The peculiar character which distinguishes this, is that of dissolving in warm water, and forming with it a solution which, when *cold*, is of a gelatinous consistence, more or less firm according to the proportion of water. It forms, *too, an* insoluble compound with tannin; and this affords a test of great delicacy, by which it is discovered. Corrosive muriate of mercury does not precipitate it, by which it is distinguished from albumen. The acids dissolve it, and partially decompose it; nitric acid disengaging nitrogen, though not in large quantity. The alkalis also dissolve it: the alkaline earths render its solution turbid. This principle, decomposed by heat, affords the usual products obtained from the decomposition of animal matter. It is the one most susceptible of spontaneous decomposition.

The Skin, which forms the external covering of the body, consists of the Cuticle, or Epidermis, and beneath this the Cutis, or true skin, with a cellular substance interposed. The Cuticle is nearly inorganic; when detached from the parts beneath, it is extremely thin and transparent. It is insoluble in water, even by long boiling, and is equally insoluble in alkohol. Alkaline solutions dissolve it, forming a kind of soap. Lime also dissolves it. The acids decompose it, sulphuric acid forming with it a soapy pulp, nitric acid staining it yellow.

The true Skin is thicker than the epidermis, and has considerable firmness and elasticity. If boiled strongly in water it is dissolved, and the solution has all the characters of gelatin, being precipitated by tannin, and nitro-muriate of tin; and attaining, when evaporated, a gelatinous consistence. Even in its dense state, it combines with tannin slowly, and hence the change which it suffers in the operation of tanning, the combination taking place with more celerity, as the skin is more soft and flexible.

Acids decompose skin; nitric acid, which acts on it most readily, causing an evolution of nitrogen gas and prussic acid, and a formation of oxalic acid, the skin acquiring also a yellow colour. It is soluble in alkaline solutions. In its humid state it is liable to putrefaction, but suffers it more slowly, as the skin is more dense and firm. Decomposed by heat, it affords the usual products of animal matter.

The Cellular Fibre interposed between the cutis and cuticle, has been little examined. It is the seat of the colour of the surface of the body, and the colouring matter diffused through it can be acted on through the cuticle, the skin of the negro being whitened by oxy-muriatic acid.

The MEMBRANES, which compose a large portion of the soft solids, forming the cellular texture, the coats of the vessels, and the coverings of the viscera, appear to be of the same nature. They have similar flexibility, and dissolve in water, forming gelatinous solutions.

Glue is formed by boiling the skin and membranes in water strongly, and reducing the solution by evaporation so far, that on cooling it becomes concrete. It differs in the degree of consistence which it gives to water, as prepared from different substances; and although it is essentially gelatin in all these varieties, it differs somewhat in its chemical properties. The more firm and dense it is, its solution is less easily acted on by tannin, and it is also much less liable to putrefaction, than when obtained in that form in which it is soft and tremulous.

Sect. XIII.—*Of the Muscular Fibre.*

The Muscles, or Flesh of animals, have a distinctly fibrous texture. Their basis appears to be Fibrin not much changed, with which are intermingled small portions of albumen, gelatin, a peculiar extractive matter, and saline matter, these being derived, in part at least, from the blood diffused by the medium of the blood-vessels. To this, too, the colour is owing, as when washed with water, the muscular substance remains white, and similar in appearance to fibrin. The water employed in this operation holds dissolved the other principles. When heated, the albumen is separated from it by coagulation in flakes; if these are removed, and the liquor evaporated, it becomes gelatinous, a little fatty matter separating and collecting on the surface; and by this simple experiment the albumen and gelatin are detected. Besides these, a portion of a peculiar extractive matter is obtained by evaporating the jelly to dryness, and treating it with alkohol, the alkohol dissolving the matter, and yielding it, by evaporation, in a solid form. It is of a brownish colour, has a pungent odour, and a taste somewhat aromatic. Lastly, the saline matter is procured by boiling water on the muscular fibre, previously washed; it consists of phosphates of soda and ammonia, and phosphate and carbonate of lime. As they remain in the muscle after washing, and are only extracted by boiling, they are probably essential to its composition; they differ, too, in their proportions, at different periods of life, being more abundant in the coarse and rigid muscular fibre of adult animals, than in the more delicate fibre of those who are young. In the latter, too, the proportion of gelatin is larger than in the former.

When the flesh, without any preparation, is boiled in water, the gelatin and albumen are more completely extracted and dissolved, and the fibrin is diffused in threads in the boiling liquor. The albumen coagulates, the gelatin is detected by the abundant precipitate formed with tannin, or if the liquor be sufficiently evaporated, it renders it gelatinous.

When the muscular substance is exposed to the air, it soon becomes tainted, and at length putrid, a change principally arising from the presence of gelatin, which is peculiarly liable to putrefaction when humid; and, accordingly, if it has been removed by washing, the flesh remains much longer sound. If the air is excluded, and the flesh immersed in water, it is gradually converted into a fatty substance, a species of decomposition which is afterwards to be considered.

Muscular fibre, decomposed by heat, afford the usual products of animal matter. Its residual charcoal gives, by incineration, carbonate and phosphate of lime.

The acids decompose the muscular fibre, with results nearly similar to those afforded by their action on fibrin. Nitric acid disengages nitrogen gas, with a portion of carbonic acid gas, and the principal product is an unctuous substance of a yellow colour, rancid smell, bitter taste, and sensibly acid. The unctuous matter, according to Fourcroy and Vauquelin, may be separated by the action of alkohol from the acid. The latter is a substance altogether peculiar, to which these chemists *have given the* name of Yellow Acid, and which they suppose to have some relation to the yellow and bitter principle of bile. It is of a deep-yellow colour, has an intensely bitter taste; and its acidity, which is displayed in its power of reddening the vegetable colours, and combining with the alkalis, they conclude, belongs to it, and is not derived from any portion of the nitric acid employed in its formation adhering to it.

SECT. XIV.—*Of Tendon, Ligament, Cartilage, Horn, &c.*

THESE substances appear to have albumen for their basis; they pass insensibly into each other, and they form the transition into shell and bone.

The TENDONS have a considerable degree of toughness and elasticity; their texture is fibrous. They are scarcely affected by water, unless by long boiling, when a gelatinous solution is said to be obtained.

The LIGAMENTS are distinctly fibrous in their texture, and have much firmness and cohesion. When boiled in water, they afford a portion of gelatin, but the entire substance cannot be dissolved, and it probably, therefore, consists of indurated albumen.

CARTILAGE has a still greater degree of induration. It is, however, sufficiently soft to be cut easily; it has also much cohesion and elasticity. It is softened by maceration in water, and the softer cartilages are, by boiling, nearly entirely dissolved. Acids do not exert much action on the matter of cartilage: when dilute or weak, they do not dissolve it; strong nitric acid decomposes it; alkalis dissolve it. The base of cartilage, and of many of the other animal solids, Mr Hatchet inferred from experiment to be indurated albumen, and to be analogous, in chemical properties, to pure coagulated albumen dried. In these solids, it is usually combined with portions of gelatin, and of earthy matter, principally phosphate of lime, but in cartilage it appears to be nearly pure.

Horn has a considerable similarity to cartilage, differing from it principally in a greater degree of induration. When boiled strongly in water, it affords a small quantity of gelatin, the most flexible horn yielding the largest quantity; the residual matter is indurated albumen, with a small quantity of phosphate of lime. It is singular, however, that the horn of the stag is of a very different nature, consisting principally of gelatin, with phosphate of lime, and being therefore analogous to bone. Hoof is, both in mechanical structure and chemical composition, similar to horn; as are also the matter of the Nail, the Scales of insects, Feather and Quill; all of these, when boiled in water, giving scarcely any gelatin, but consisting apparently of indurated albumen.

Hair, though apparently very different from these substances in mechanical structure, is similar in its chemical nature. When boiled with water, it affords a small portion of gelatin, and the residuum, Mr Hatchet found, had all the characters of indurated albumen. The hair also contains an oily matter, which may be extracted by alkohol macerated on it; in this the colouring matter appears to reside, as it is always obtained of the colour of the hair.

Wool is merely a finer hair. It has scarcely been chemically examined, but it has one of the characteristic properties of indurated albumen, that of forming a saponaceous compound with alkalis.

Silk is connected with these substances in physical properties and chemical constitution, though there are also some peculiarities with regard to it. It is in fine fibres, of different shades of colour, naturally covered with a kind of varnish which communicates stiffness and elasticity; both the colouring matter and varnish are removed by the successive application of weak alkaline leys, alkohol, and diluted muriatic acid. The pure silk is insoluble in water, even at a boiling heat; it is also insoluble in alkohol. The fixed alkalis dissolve it, and decompose it, causing an exhalation of ammonia. The acids also dissolve and decompose it. Nitric acid disengages nitrogen gas, and forms prussic and oxalic acids, with a portion of a peculiar matter, named by Welter, who observed its production, Bitter Principle, from its intensely bitter taste, of a yellow colour, soluble in water and in alkohol, crystallizable and inflammable, and which appears to be the same product with the yellow bitter acid already noticed, as produced in the decomposition of the muscular fibre, by nitric acid.

The silk-worm forms along with the silk an acid liquor, which was supposed to be a peculiar acid, and received the name of Bombic acid. There is reason to believe that it is merely acetic acid, weak and impure.

Sect. XV.—*Of Bone and Shell.*

Bone and Shell differ from the preceding substances in their greater induration, derived from the larger quantity of earthy matter that enters into their composition. In bone the earthy matter is principally phosphate of lime, in shell it is carbonate of lime, but these are intermixed in the different varieties; and there are intermediate substances, the crustaceous coverings of certain marine animals, and of zoophytes, in which the proportions of phosphate and carbonate are nearly equal.

Bone admits of a simple analysis, by which its immediate principles are discovered. By boiling in water, a liquor is formed, which becomes of the consistence of a jelly on cooling, proving the presence of a large proportion of gelatin. If the bone, without boiling in water, be digested in dilute muriatic or nitric acid, the gelatin and earthy matter are dissolved, and a transparent cartilaginous substance remains, retaining the figure of the bone. By calcination in the open fire, the animal matter is burnt out, and the earthy matter is obtained, which farther analysis discovers to be phosphate of lime; it is likewise separated during the decoction of bone under increased pressure, an experiment which proves that it pre-exists in the bone, and is not formed during the calcination. Lastly, during the boiling of bone in water, a portion of oily matter separates, and collects on the surface. By these experiments, then, bone is proved to be composed of gelatin, cartilage, phosphate of lime, and unctuous matter, the last being probably adventitious, and derived from the marrow diffused through the layers of bone. Some other principles appear to be present, too, in smaller proportion. A little carbonate of lime exists in recent bone; and a larger quantity, with a portion of sulphate of lime, are found in calcined bone, the greater part of which is probably formed during the calcination. Berzelius has discovered fluate of lime; and in the bones of the lower orders of animals, there is a portion of phosphate of magnesia. The proportions of all these ingredients must be various in bones in different states; the earthy matter becomes more abundant as the animal advances in life. The quantity of gelatin extracted by boiling in water is from 25 to 50 in 100 parts, the remainder being principally phosphate of lime.

When bone is exposed to heat gradually raised, it is decomposed, a large quantity of carbonate of ammonia is volatilized, formed by new combinations of the elements of its animal matter. This is accompanied with a portion of a very fetid oil, and with quantities of prussic and sebacic acids, carburetted and sulphuretted hydrogen gases. The bone remains charred, but when urged with a strong heat in an open fire, it becomes white; this residual matter, which retains the figure of the lime, being composed of its earthy salts. It is analysed by the action of the acids. On the addition of any of the more powerful acids, an effervescence is excited from the disengagement of carbonic acid, and a pungent smell, arising probably from the evolution of prussic and carbonic acids. If sulphuric acid has been employed, sulphate of lime remains, and the liquor obtained by washing the materials is a solution of superphosphate of lime. If nitric acid has been used, the entire calcined bone is dissolved with effervescence; from the solution phosphate of lime is precipitated by the addition of ammonia; by adding to the residual liquor nitrate of barytes, sulphuric acid is detected; and from the quantity of it, the proportion of sulphate of lime may be inferred; and the proportion of carbonate of lime may likewise be inferred from the quantity of carbonic acid disengaged during the solution.

Bone is not much liable to spontaneous decomposition, the re-action of the elements of its animal matter being in a great measure prevented by the inert earthy matter in which it is involved, and the solidity which this communicates to it. In fossil bones, or those which have been long buried in the earth, the animal matter is removed by slow decomposition, and its place supplied by carbonate of lime, conveyed probably by slow infiltration.

The ENAMEL of the teeth is evidently of the nature of bone. It has the peculiarity, however, of containing a very small proportion of animal matter. In dissolving in acids, it produces a slight effervescence, and contains therefore a portion of carbonate mixed with its phosphate of lime. Morichini announced the presence of fluoric acid in the enamel, vapours of it being disengaged by the action of sulphuric acid, and also the presence of the same acid in ivory, or the enamel or outer layer of the fossil-teeth of the elephant.

SHELL, or the hard covering with which the bodies of many marine, and also of a number of land animals are covered, is in structure similar to bone. It was known, however, to contain a large proportion of carbonate of lime; and Mr Hatchet's experiments have shewn, that it is this which forms its principal earthy matter, mixed sometimes with small proportions of phosphate of lime. Marine shells are of two descriptions, either of a porcellaneous aspect, with an enamelled surface and fibrous texture, or composed of the substance called Nacre, or

Mother of Pearl. The former afford no trace of phosphate, but consist of carbonate of lime, with animal matter, which Mr Hatchet considers as indurated albumen, in small proportion. The latter also contain carbonate of lime, but the animal matter is in much larger proportion; it often constitutes even a large part of the shell, and is so highly indurated as not to be gelatinous. In shells of this kind it appears to be deposited in layers, alternating with corresponding thin layers of carbonate of lime. Mother of pearl, and pearl itself, are of this structure and composition; and their waved appearance, and iridescence, and nebulous semi-transparency, appear to arise from it.

The substance of zoophytes, comprising the varieties of madrepore, millipore, and tubipore, consists likewise of carbonate of lime, with animal membrane. The substance analogous to shell, which forms the covering of crustaceous marine animals, has the same cementing animal matter as other shells, but with this are united both carbonate and phosphate of lime. The shells of the eggs of birds are of similar composition. Both form therefore a substance intermediate between Bone and Shell.

SECT. XVI.—*Of Fat, Spermaceti, Sebacic Acid.*

ANIMAL fat has nearly the same properties as vegetable oil. In the living animal body it is nearly fluid, and is contained in distinct cells; after death it in the greater number of cases becomes concrete, and more or less firm, and is freed from the membranous matter by melting it out, a little water being usually added to prevent the heat from being applied too strong. As thus obtained, it is usually insipid and inodorous; when of a soft consistence it forms lard, when firmer, tallow. As obtained from a number of marine animals, it remains fluid, and has an offensive smell.

Fat is insoluble either in water or in alkohol. Exposed to the air it is liable to become rancid, a change which appears to be connected with the absorption of oxygen. It melts easily; by raising the heat it is rendered more acrid, a pungent vapour arises from it; and in close vessels it is decomposed, the oily fluid which distils over being changed in its properties, and this being accompanied with a production of acid, and a disengagement of carbonic acid, and carburetted hydrogen gases. Ammonia *in small quantity* is also produced in this process.

Fat is highly inflammable, and affords by its combustion water and carbonic acid. Carbon and hydrogen are therefore its chief elements. The production of an acid in its destructive distillation, indicates the presence of oxygen, and that of ammonia the presence of nitrogen in inconsiderable quantities.

The acids act chemically on fat. Sulphuric acid chars it. Nitric acid mixed with it in small quantity gives it a firmer consistence; distilled from it, it is decomposed, and acetic and oxalic acids are formed.

The alkalis combine with fat, and form with it perfect soaps. It forms also saponaceous compounds with some of the earths; and it unites with a number of the metallic oxides, acquiring in the combination a firm consistence. It even facilitates the oxidation of some of the metals, as copper and quicksilver, by the atmospheric air.

The acid obtained in the distillation of fat was regarded as a peculiar one, and as such received the name of SEBACIC ACID. The common process for obtaining it consisted in exposing fat, in mixture with lime, to a strong heat in an iron pot: the acid formed from the decomposition of the fat is attracted by the lime; and the salt thus formed, being extracted by lixiviation, and freed from any adhering unctuous matter by calcination, is, by a second solution in water and crystallization, obtained pure and white. On adding to it sulphuric acid, the sebacic acid is separated, and may be procured by distillation. It has an acrid suffocating odour, is volatile, and reddens the vegetable colours.

From the researches of Gren and Thenard, it appears, however, that this acid is merely the acetic in an impure state. Still, according to Thenard, there is a proper sebacic acid. It is produced by distilling fat, and treating the product with hot water; to the filtered liquor acetate of lead is added; the precipitate which is formed is heated in a retort with sulphuric acid, a watery liquid distils over, and there floats on the liquor of the retort, an unctuous-like substance, soluble in water when boiled with it, and which, on the water cooling, is deposited in crystalline needles. This Thenard regards as the sebacic acid; its taste is slightly sour, it reddens litmus, is soluble in water and in alkohol, and melts at a moderate heat, assuming an unctuous appearance. It combines with the alkalis and earths, and forms soluble salts.

SPERMACETI, the substance deposited from the oil found in the head of several species of whale, particularly the Physeter Macrocephalus, though analogous to fat, differs from it in several of its properties. It is of a flaky texture, soft and brittle, white and brilliant; it melts at 113, and by raising the heat may be volatilized with little change, though by repeated distillation it is decomposed. It burns with a clear flame.

A property distinguishing it from fat, is that of solubility in alkohol and in ether. In alkohol it is very sparingly soluble. It dissolves more rapidly and abundantly in warm ether, but is precipitated on cooling. Oil of turpentine also dissolves it while warm, and allows it to separate when cold.

The alkalis form with spermaceti soaps less perfect than those with fat, and much less soluble. The acids have little effect on it.

This substance is similar in its properties to that which has been already noticed as forming the basis of biliary calculi, and also to that formed by the slow decomposition of muscular fibre; and the whole as a genus has been distinguished by Fourcroy by the name of Adipocire, denoting it as a substance intermediate between fat and wax.

SECT. XVII.—*Of the Cerebral Pulp.*

THE soft pulpy matter which forms the substance of the brain, has been submitted to chemical examination, and the results prove it to be different from any other animal principle, though on the whole analogous to albumen. It speedily suffers decomposition when exposed to the air, but immersed under water, may be preserved long without much change. Heated moderately it coagulates, a portion of watery liquor separating from it. When diluted in water, it suffers a similar coagulation by heat; and alkohol and acids produce nearly the same change. Acids decompose it. Alkalis dissolve it, forming saponaceous compounds, and causing an ammoniacal exhalation. By the action of alkohol, aided by heat, there is produced not only the coagulation of the albuminous matter, but a substance is dissolved, and separated analogous to adipocire. Re-agents discover in it the presence of phosphates, principally phosphate of soda and of lime. It is decomposed by heat, and when dry, inflames if the air is admitted, and in its combustion produces a considerable quantity of sulphurous acid.

CHAP. III.

OF THE DECOMPOSITION OF ANIMAL SUBSTANCES FROM THE RE-ACTION OF THEIR ELEMENTS.

THE elements of which animal matter is composed having all mutual affinities, and these being nicely adjusted in the combinations which constitute its several varieties, they are liable to be altered by very slight changes of circumstances; and hence the character eminently distinctive of the animal products,—their extreme susceptibility of decomposition. The results of the changes which they suffer from the new combinations into which their elements enter, are different according as these are established at a natural temperature, or by the application of heat; and these two species of decomposition require therefore to be considered apart.

SECT. I.—*Of the Decomposition of Animal Substances at a high temperature.*

THE general result of the decomposition of animal substances by the application of heat, is the transition of their elements into binary combinations. From the union of portions of their nitrogen and hydrogen, ammonia is formed; carbon combining with oxygen forms carbonic acid, and frequently carbonic oxide; and with the addition of hydrogen, empyreumatic acid; the combination of carbon with hydrogen gives rise to the formation of empyreumatic oil, and of different varieties of carburetted hydrogen; sulphur, and phosphorus, are disengaged partly in combination with hydrogen, and partly remain united with oxygen in the states of sulphuric and phosphoric acids, combined with the alkalis or earths of the animal matter. These products are much diversified with regard to their proportions, according to the proportions of the elements in different animal products, and are varied too by the circumstances of the decomposition, such as the state of humidity and the degree of heat.

A peculiar product is obtained in many of these cases of decomposition,—Prussic acid, the chemical history of which still remains to be delivered. Its existence as a product of vegetation has been already noticed; it is usually by the decomposition of animal matter that it is obtained.

It enters along with oxide of iron into the composition of the blue pigment known by the name of Prussian Blue. This substance is prepared by calcining dried blood with the potash of commerce, lixiviating the residual matter with successive portions of boiling water, and adding to the ley reduced by evaporation, a solution of sulphate of iron, and of common alum. A precipitate is thrown down of a greenish colour, which assumes a very rich blue, when washed with a little diluted muriatic acid.

Macquer discovered, that from this substance the Prussian Blue of commerce, the principle which, united with oxide of iron, produces the blue colour, may be abstracted by the action of an alkali, the alkali combining with it, so that by adding it to a solution of a salt of iron, the blue precipitate is reproduced. Scheele completed the discovery with regard to the nature of this colouring principle, by obtaining it in an insulated state. This he did by subjecting the alkali which had been combined with it to distillation, with the addition of sulphuric acid. The liquor, which passed over with a gentle heat, had a peculiar smell and taste, and added to the salts of iron, produced a deep blue tint.

Scheele found it difficult to obtain this principle free from oxide of iron, to which it has so strong an affinity as to carry a portion of it into any combination into which it enters. The process which he found to succeed is complicated, but it is still the only one by which we procure it in a state of purity. Two ounces of prussian blue, and one ounce of red oxide of quicksilver prepared by nitric acid, are put into a flask with six ounces of water, and boiled for some minutes with constant agitation. It is then poured on a filtre, and the matter which remains on the paper, is lixiviated with two ounces of hot water. The liquid which has passed through, is a combination of the colouring matter with oxide of quicksilver, without any oxide of iron. This he found could not be decomposed by acids, alkalis, or lime; and the colouring matter could be separated only by reducing the mercurial oxide to the metallic state. To effect this, the filtered solution, from the above quantities of materials, is poured on an ounce and a half of iron-filings, free from rust, to which are added three drachms of sulphuric acid. The oxide of quicksilver is reduced to the metallic state. The clear liquor, after the action has ceased, is poured off and distilled. When the fourth part has come over, the whole of the colouring matter is obtained, as it is more volatile than water, and rises first. There is a slight contamination of sulphuric acid, which may be removed by distilling from a little chalk.

The claims of this substance to be ranked as an acid are doubtful; its taste is not sour, and it does not redden the delicate vegetable colours. Its acidity is displayed only in its neutralizing the alkaline properties; and even this action is scarcely exerted by it, except when it is in combination at the same time with a portion of a metallic oxide. It then, however, forms neutral salts, very distinctly marked, these of course being ternary compounds.

Prussic acid has a peculiar odour, resembling that of peach blossom; it is a powerful narcotic; its watery solution has a sweetish pungent taste. Such is its volatility, that even at a common temperature it escapes rapidly from the water which holds it dissolved. In solution in water, it appears too to suffer spontaneous decomposition.

This acid combines with the alkalis and earths, forming compounds denominated Prussiates, and which scarcely admit of examination, as they are decomposed by the agency of water alone. According to Scheele's observation, it does not neutralize the properties of the fixed alkalis, even when added in excess; and ammonia retains its peculiar odour when there is a similar excess; its effects on the earths with which it combines are similar. It does not act on the metals, but combines with several of the metallic oxides; with oxide of quicksilver it forms a crystallizable salt By complex affinity its combinations with the metallic oxides are more easily effected, precipitates being formed by adding prussiate of lime, or prussiate of potash, to the solutions of the different metals. These are probably ternary compounds of the prussic acid, with part of the potash or lime, and the metallic oxide. All these compounds are more permanent than the alkaline or earthy precipitates; the metallic oxide, by the affinity it exerts to the acid, resisting its decomposition.

Of these ternary compounds, those with oxide of iron are the most important; they differ according to the proportions, and also according to the oxidation of the metal.

The blue precipitate which forms the basis of prussian blue, appears to be a compound of this kind, *for although* it consists principally of prussic acid and oxide of iron, the acid appears to carry along with it a portion of the alkali into the combination. It may be obtained from any of the salts of iron by adding what is called the Prussian Ley, prepared from calcined blood and potash, to the solution of the metallic salt. The iron requires, however, to be at the maximum of oxidation, for when a salt at the minimum is employed, the precipitate is nearly of a white colour; from exposure to the air, it soon acquires a blue shade. According to Berthollet, the different results obtained in the action of the prussian ley on the salts of iron, at a high and at a low degree of oxidation, depend principally on the affinity exerted by the oxide to the acid with which it is combined being different in these states, so that when it is at the maximum it is more easily abstracted, and enters into combination with the prussic acid; and hence, even from the salt at the minimum, the blue precipitate may be produced by circumstances which do not change the state of oxygenation, as by mere dilution with water. In its precipitation, as there is in the ley prepared from blood an excess of alkali, the colour of the precipitate is green from the intermixture of yellow oxide of iron, but this is removed by washing with dilute muriatic acid. The alum added in its preparation is designed to afford a portion of argillaceous earth, which mingling with the blue precipitate, gives it more consistence, and increases the quantity, while the colour still remains sufficiently deep. It is therefore always present in the prussian blue of commerce. The sulphate of iron is the salt employed, as being the most economical.

There is a different compound, a triple compound of prussic acid, alkali, and oxide of iron, which remains to be noticed. By boiling solution of potash on prussian blue, a portion of the prussic acid is attracted by the alkali, as has been already stated; and hence this liquid throws down a blue precipitate from the salts of iron. But it contains too a portion of oxide of iron, which the prussic acid has carried along with it into combination with the potash, as is rendered evident by the simple experiment of adding to it an acid, so as to saturate part of the alkali, a portion of prussian blue being precipitated.

The precipitate formed by this liquor, on adding it to a salt of iron, being extremely deep in its colour, it has been much used as a test to discover the presence of that metal. In its common state, however, as prepared by boiling solution of potash on prussian blue, it cannot form a test of any delicacy, for from the quantity of oxide of iron existing in its composition, a source of error is introduced, a blue precipitate being produced, either where any free acid is present, or when an acid is evolved by the action of the test itself. It has therefore been an object of much investigation, to avoid this by removing this oxide of iron. It now appears that the entire removal of the oxide is impracticable; its presence, to a certain extent at least, is necessary to maintain the constitution of the prussic acid, this acid, when combined with potash alone, being decomposed by the agency of water. Still the oxide of iron may be so far removed, that what remains is retained in combination with the prussic acid with such force as is not to be separated by the action of another acid; and from the compound in this state used as a test, no error *can arise*. Different processes have been given to obtain it. The liquor prepared from calcined blood and potash answers tolerably well, for although it contains a portion of iron derived from the blood, this is much less than is contained in that prepared by digesting an alkaline solution on prussian blue. And this affords the simplest method of preparing the test in a state fit for use. This test not only precipitates iron from its solution, but also the greater number of the metals; and as the precipitates it throws down are usually of a deep colour, it serves to discover them. The precipitate it forms from the salts of copper is of a delicate and permanent brown colour, and has been introduced as a pigment.

The ternary compound of prussic acid with potash and oxide of iron, which forms the above test, may, by evaporation, be obtained in a crystallized state; its crystals are of a yellowish colour. The compounds of the acid and oxide, with other salifiable bases, scarcely require notice. That with barytes is obtained in rhomboidal crystals of a yellow colour, sparingly soluble in water; that with strontites is less disposed to crystallize, but is more soluble; that with lime is deposited in minute crystals of a yellowish tinge.

Prussic acid being formed from the decomposition of animal matter, may be inferred to be composed of its usual elements; it accordingly, when decomposed by heat, affords the usual products, and in particular a large quantity of ammonia. Scheele gave an instructive experiment with regard to its formation. It consisted in raising a mixture of charcoal powder, and sub-carbonate of potash, to a red heat, and introducing to it muriate of ammonia. The residual matter afforded, when washed with water, a ley, which threw down a blue precipitate from sulphate of iron. Prussic acid had therefore been formed, the ammonia affording hydrogen and nitrogen, the charcoal carbon, and any portion of oxygen required might be derived from the water contained in the salts. The acid has since been formed, by passing ammonia, in the gaseous form, over ignited charcoal in a tube,—an experiment in which the same elements are obviously present.

In these cases, though oxygen may be supplied to a certain extent, it can be only in sparing quantity; and these synthetic experiments prove, that no large quantity of this element enters into the composition of this acid. This has been inferred, too, from its analysis, as when decomposed by heat, it affords scarcely any carbonic acid, the elastic fluid disengaged being carburetted hydrogen; and some chemists have even been disposed to conclude, that it contains no oxygen. All the species of carburetted hydrogen gases, however, probably contain oxygen; a portion of carbonic acid is also always produced in the decomposition of the prussiates. These facts warrant the conclusion, that oxygen enters into the composition of prussic acid; and, accordingly, Vauquelin found, that in its formation from ammonia and charcoal, at a high temperature, the quantity is much increased if a substance be added which can afford oxygen.

Prussic acid is partially decomposed by oxy-muriatic acid, which, in producing this change, yields its oxygen. The prussic acid thus acquires a stronger smell, becomes more volatile, and exerts less powerful affinities; it precipitates oxide of iron green from its salts, the precipitate becoming blue from exposure to light, or the action of substances which abstract oxygen. The acid, in this state, has been named Oxy-Prussic Acid. If still farther impregnated with oxy-muriatic acid, and exposed to light, it is converted into an oily-like substance, having an aromatic odour, not soluble in water, and having no acidity.

SECT. II.—*Of the Spontaneous Decomposition of Animal Substances at low temperatures.*

THE spontaneous changes which animal matter undergoes from the re-action of its elements, are various, according to the circumstances under which it is placed.

If it be completely excluded from air and moisture, it decays with extreme slowness; it is finally changed, however, so that nothing remains but an earthy-like substance.

If those animal substances which are not soluble in water, those, for example, which consist principally of fibrin, as the muscular fibre or flesh, be kept immersed in water, the soluble parts are removed, and the fibrin is gradually changed into a fatty matter, similar to spermaceti. A similar change is produced by the agency of very diluted nitric acid on the muscular fibre. In either case the nitrogen and phosphorus seem to be disengaged, probably in combination with hydrogen; while another portion of the hydrogen, with perhaps a quantity of oxygen, combined with the carbon, form the residual matter.

When atmospheric air is not entirely excluded, and when moisture with a certain degree of heat is present, the process named Putrefaction commences. The elements of the animal matter enter into new combinations, which generally pass off in the gaseous form; and an inconsiderable quantity of earthy matter remains when the process is finished. The precise nature of these combinations has not, from the offensiveness of the process, been accurately observed; and they probably vary according to the nature of the animal matter, and the circumstances under which it is decomposed. Ammonia formed by the union of the nitrogen and hydrogen of the animal matter, is always disengaged in considerable quantity. Phosphuretted hydrogen appears to be produced, as this gas, even when obtained pure, has the odour exclusively termed Putrid. Sulphuretted hydrogen forms another part of the vapours disengaged from putrefying substances, as these vapours have in some degree its smell, and blacken the metals,—a peculiar property of this gas. Carburetted hydrogen and carbonic acid are likewise separated. And, lastly, it is probable that not only these binary combinations, but compound gases consisting of three or more of these elements with oxygen, are formed and discharged.

As this process must necessarily be carried on at the surface of the earth, its products are diffused through the atmosphere, dissolved by water, and absorbed by the soil. They furnish the principal nutritious matter for the support of vegetables, and are again prepared for the nourishment of animals.

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